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BORIC OXIDE—ITS CHEMISTRY AND ROLE IN GLASS TECHNOLOGY

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PART I

Editor's Note: In the past we have presented to our readers several articles dealing with the chemistry of ingredients of the glass batch and their roles in glass technology.

W. A. Weyl—The role of sodium sulphate.

W. A. Weyl—The role of arsenic.

N. J. Kreidl—The role of zinc oxide.

In this article the author describes the natural occurrence of boric oxide, its chemistry and its role as a minor and a major constituent of glasses. The beneficial effects of borax as an addition to the glass batch is well known. However, the particular way in which borates affect the glass properties has often been a puzzle to both plant technologists and scientists. Recent research and the modern concept of the atomic structure of glass has made it possible to understand and explain the role of boric oxide. The article combines the experience of the glass maker in the plant with the latest results of fundamental research.

The bibliography of boric oxide in glass technology will be published with the final installment of this series.

I. Introduction

Borax, a hydrated sodium salt of the boric acid, has been known from fairly early times. Under the name "tincal" it was traded from Tibet, and its use was chiefly that of a flux in metallurgy. Mention of borax as an ingredient of glass batches can be found in the "ars Vitraria," the work which summarizes the technical knowledge of the glass melter in the 17th Century. W. M. T. Gillinder (1854) describes borax as the strongest fluxing agent available to the glass industry. Borax was used by Harcourt, as well as by Fraunhofer and Guinand, in their efforts to improve the optical glasses available in their time.

But it was not until Abbe and Schott began their systematic work on the properties of glasses that boric acid established a permanent position among the glass-forming oxides. The objective of this successful teamwork was the production of optical glasses with new and desirable dispersion and refraction properties. In this respect boric acid was found to be a constituent of extraordinary usefulness because it imparted to glass a greater dispersion for the long waves and a small dispersion for the short wave region, thus helping to contract the blue part and extend the red part of the spectrum and making the dispersion more uniform.

With the exception of the few isolated experiments, the glass melter at the middle of the past century had at its command only six elements: Silicon, oxygen, sodium, potassium, calcium and lead. Other constituents were added to the glass only in minor quantities for coloring, decolorizing and fining. The work of Abbe and Schott added 28 new elements, and their work included, among others, phosphorus, boron, lithium, barium, strontium, beryllium, thallium, bismuth, tin and fluorine. Most of these elements are still used in minor quantities or for special glass compositions. Boron, however, began its triumphant march to conquer the glass industry as a whole.

As mentioned before, Abbe and Schott were not the first to notice the valuable properties of boron as a constituent of optical glasses. What made their work succeed over that of earlier and contemporary investigators was their systematic approach to the problem, especially their efforts to control other properties besides refraction and dispersion. Other workers who succeeded in improving the optical properties of a glass did so on the expense of its chemical stability. Schott and his coworkers examined all properties of their new glasses which could possibly have a bearing on the manufacture and the use of lenses.

This classical research of Abbe and Schott added two more important properties to boric oxide as a constituent of silicate glasses. Besides its fluxing effect and its beneficial influence on the dispersion of optical glasses, it was discovered that boric acid increased the chemical resistivity and reduced thermal expansion. This discovery

seemed important enough to be explored separately. The resistivity of borosilicates towards chemical corrosion and thermal shock was an asset for their use as optical elements, but in addition it opened a new field, the chemical laboratory ware. Out of the research of Abbe and Schott grew not only a large number of new optical glasses, but thermometer glasses, laboratory ware, lamp chimneys and special glasses, such as one having a low absorption for X-rays.

Centered around boric oxide many of the original Schott glasses were improved. Boric oxide is a major constituent of the Pyrex glass group; it plays a unique role in the manufacture of Vycor glasses and is the chief acidic constituent of the modern high refractive index glasses based on rare earth oxides.

Interest in the role of boric oxide in glass, however, was not restricted to its commercial value. As soon as scientists began to think about the nature of glass and its chemistry, boric oxide became one of the centers of attraction. Under Abbe and Schott glasses were considered mutual solutions of the respective oxides or silicates. Their work was guided by the principle that the properties of a glass are more or less additive. The calculation of glass properties from factors derived for the various constituents goes back to their time. It was expected that each glass constituent contributes in its characteristic way to the properties of the final product. Silica imparts refractiveness; alkali acts as a flux and makes the glass low melting; lead oxide imparts density and a high refractive index. This relationship between the property of the constituent and that of the glass must have seemed obvious to the glass melter and the scientist of that time. One can imagine the surprise which the introduction of boric oxide into the glass caused to those concerned with its properties. Boric acid is water soluble, but against all expectations it improved the chemical resistivity of an alkali silicate glass and made it less soluble in water. Boric acid has a high thermal expansion, but it materially decreases the thermal expansion of a soda-lime-silica glass and makes it more resistant to thermal shock. Despite its low density and refractive index, additions of B_2O_3 increases these values for most silicate glasses.

Practically all properties of a glass are changed through boric oxide in the opposite direction as expected. Only if a certain percentage, between 12 and 20% is exceeded, B_2O_3 imparts its own characteristic properties to the glass. Any picture of the constitution of glass had to satisfy this phenomenon, which became known in the glass literature as the "boric acid anomaly." Not until the last decade was it possible to give a complete and satisfactory explanation for the "anomalous" behavior of boric oxide when added to an alkali silicate glass. Boric oxide had greatly stimulated scientific research on the constitution of glass, on its atomic structure and on this puzzling influence which the thermal history exerts upon its properties. The boric acid anomaly is a perfect example for the statement which Faraday once made to Tyndall when he reported about an "anomalous" magnetic phenomenon: "The more we can enlarge the number of anomalous facts and consequences, the better it will be for the subject, for they can only remain anomalies to us while we continue in error."

II. Sources of Boric Acid

There exists no established theory concerning the geochemistry of boric acid and the natural borates. Three different explanations were given and there seems to be no possibility for proving or disproving one of them. In some places boric acid is found to be associated with ammonia, e.g. in the famous "soffioni" or "fumaroles" of Tuscani (Italy) and in the Borax Lake, Lake Co., California. As ammonia is very uncommon in the mineral kingdom, it was suggested that both boric acid and ammonia originate from the same parent substance: boron nitride. Boron nitride is a substance which has been made synthetically in the laboratory and which can form boric acid and ammonia when heated with steam, but this compound has not been found in nature. Until its occurrence in nature has been established, we must consider the explanation given by R. Warrington (1854), as well as H. Sainte Claire Deville and F. Wöhler (1858), as purely hypothetical.

The same holds true for another explanation proposed by Dumas, who mentioned boron sulfide, B_2S_3 as a possible source of boric acid. A. Payen (1841) in his description of the Tuscan fumaroles uses this theory to account for the presence of hydrogen sulfide. Both substances, boron nitride and boron sulfide, have not yet been found as minerals, but it is not impossible that they occur in deeper regions of the earth crust. If one assumes them to be the source of boric acid, one has at the same time a plausible explanation for the simultaneous occurrence of ammonia and hydrogen sulfide according to the equation:

$$BN + 3\ H_2O = H_3BO_3 + NH_3$$
$$B_2S_3 + 6\ H_2O = 2\ H_3BO_3 + 3\ H_2S$$

A third explanation is based on the decomposition of known borosilicate minerals, such as tourmaline. This mineral can produce boric acid when treated with steam. At the same time the action of steam upon sulfidic ores may account for the hydrogen sulfide, but there is no mineral known which would produce ammonia.

There are a great number of boron minerals, borates, borosilicates, even a borophosphate. However, the number of commercially important minerals is scarcely more than half a dozen. In this treatise on the role of boric oxide in glasses, we will go more into the mineral economy of boron than the title suggests. The reason for doing so is the importance which economic considerations play in the use of boric acid in the glass industry. Its use for many purposes is restricted through its cost, and as the cost of boric acid went down in the last decades its application increased.

The first borax mined in the United States was obtained from lake muds; it was the natural borax or tincal (1864-1872). In 1872 the mineral ulexite, a sodium-calcium borate of the formula $Na_2O \cdot 2\ CaO \cdot 5\ B_2O_3 \cdot 16\ H_2O$ became the chief source of borax. In the beginning of this period ulexite was collected from the borax marshes. Its occurrence was erratic and the material was of low grade. In 1887, however, massive ulexite was discovered and with it a calcium borate, colemanite, which had the composition $2\ CaO \cdot 3\ B_2O_3 \cdot 5\ H_2O$. In 1925 the picture again changed when high-grade deposits of borax and Kernite were found, and when the deposits of Searles Lake became one of the major sources of boric acid.

In Table I the borate minerals of known commercial value are listed with their chemical formula and their B_2O_3 contents.

TABLE I

Name	*Chemical Formula*	*B_2O_3 Content*
Ascharite	$2\ MgO \cdot B_2O_3 \cdot H_2O$	41.38
Boracite	$5\ MgO \cdot 7\ B_2O_3 \cdot MgCl_2$	62.15
Borax (Tincal)	$Na_2O \cdot 2\ B_2O_3 \cdot 10\ H_2O$	36.51
Colemanite	$2\ CaO \cdot 3\ B_2O_3 \cdot 5\ H_2O$	50.81
Kernite (Rasonite)	$Na_2O \cdot 2\ B_2O_3 \cdot 4\ H_2O$	50.96
Pandermite	$4\ CaO \cdot 5\ B_2O_3 \cdot 7\ H_2O$	49.84
Sassolite	$B_2O_3 \cdot 3\ H_2O$	56.30
Ulexite	$Na_2O \cdot 2\ CaO \cdot 5\ B_2O_3 \cdot 16\ H_2O$	42.96

It is very possible that all these minerals have formed from the volatile H_3BO_3 which came to the surface from solfataras, hot springs, and other volcanic activities.

Only little of the boric acid, the sassolite remained uncombined; most of it reacted with the alkali and lime of the reactive volcanic ashes to form ulexite.

In the following paragraphs a brief outline shall be presented giving the borax production of the more important boron-producing countries.

Argentina. The production of borate minerals in Argentina averages about 700 tons a year which is sufficient for the domestic consumption of this country. Like other South American countries, such as Bolivia, Chile and Peru, the borax-producing regions are too remote to justify the transport at present prevailing low prices.

Chile. Borate mining in Chile began as early as 1852 in the pampa of Tamarugal. At one time up to 40,000 tons of borates per annum were produced. Chile has large borate deposits in the Atacama desert region.

Germany. In connection with the salt deposits of Stassfurt, a small amount of iron-containing boracite, stassfurtite has been mined.

India. From a historical viewpoint the Indian-Tibet borax trade is interesting, but its importance has dwindled with the discovery of the large California deposits. One might expect that the present interests in India in building up a domestic glass industry will result in a greater interest in Indian deposits. Borax is still worked to a small extent in the region of the Puga Valley, which is situated at an elevation of 15,000 ft. in the Ladakh district of Kashmir.

Italy. The borax industry in Italy originated in 1807 and is now carried on in an area of about 100 sq. miles between the Cornia and Cecina Valleys in the province of Pisa, Tuscany. The output of boric acid is about 5,000 tons per annum.

Peru. At one time Peru was an important producer of ulexite, but since 1917 the output has never exceeded 250 tons in any one year. The most important occurrence is Las Salinas, on the boundary between the departments of Anequipa and Moquegua.

Russia. Before 1936 the Soviet-Russian industry depended on import, but in 1934 the Inder Lake deposits were discovered, which made her self-sufficient. This deposit is situated east of the Ural River, between the Caspian Sea and the city of Uralgsk. The deposit contains ascharite, boracite and some poorer boron minerals.

Tibet. The borax industry of Tibet has been carried on continuously since 1563. Its output reached a peak in 1885, when about 1600 tons were exported. Hot springs rich in boric acid occur at an altitude of over 15,000 ft. north of Lhassa. Several borax fields have been observed within the triangular area between Rudok, Thok-Jaluk and the Manasarowar Lakes.

Turkey. Since ancient times a mineral named pandermite, a variety of colemanite, has been mined in Anatolia. The name is derived from the port of Panderma on the sea of Marmora. The modern working of the deposits, which is now carried on by underground methods, began in 1865, the mineral being first marketed in Europe in 1868.

United States. Borax was first produced in the United States in about 1864, and the annual output was less than 3,000 tons. When colemanite was discovered (1883) the production increased. Beginning with 1899 the production increased considerably, fluctuating between 18,000 and 60,000 tons. In 1933, the production exceeded 200,000 tons, so that at the present time the United States is producing the greater proportion of the world's annual output of boron minerals. The whole of the output of the country now comes from three sources in California where supplies are very extensive.

On account of the different types of deposits which have been worked, the cost of borax has undergone drastic changes. Kernite is cheaper than colemanite both in respect to mining and treating. Thus there are still large reserves of colemanite left unworked.

A few figures give a lively picture of the way the price of borax has gone down, and how this material became more and more available for the glass industry.

TABLE II

PRICES OF BORAX BETWEEN 1864 AND 1942

Year	*$ per lb. Borax*	*Year*	*$ per lb. Borax*
1864	0.39	1907	0.06
1866	0.33	1910	0.04
1876	0.10	1934	0.01 4/5
1890	0.07	1936	0.02
1900	0.07	1942	0.02 1/4

III. The Chemistry of Boric Oxide

Although the two elements boron and silicon belong to different groups in the periodic system of elements, they show a great similarity in the properties of their compounds with oxygen, nitrogen, sulfur, the halogens and carbon. Boron carbide is one of the hardest materials known, and it is like silicon carbide the only compound other than the oxide which is of interest to the glass technologist. No boron compounds other than the oxide and the derivatives thereof, the borates, are of any practical importance at the present time. Possible applications of the boron trifluoride shall be mentioned.

1. Orthoboric acid. There is, however, one major difference between the two oxides or between boric acid and silicic acid; namely, the properties of silicic acid are governed by its tendency to form polymers of high molecular weight. Silica itself, whether in the form of cristobalite or of the silica glass, must be considered a huge molecule, where all atoms are linked together with strong binding forces. The high melting point of cristobalite indicates strong forces acting between the constituing units. The same holds true for the aqueous solutions of silicic acids. Their tendency to polymerize leads to irreversible gels and makes aqueous solutions extremely unstable. Boric acid, on the other hand, is water soluble

and has a relatively high volatility in the presence of water vapor. Addition of mineral acids to alkali borates produces orthoboric acid, H_3BO_3, which can be easily recrystallized from its aqueous solutions. Its solubility decreases rapidly with decreasing temperature. Water at 80° C. dissolves 16.8% H_3BO_3, but at 12° C. only 3.0%.

Boric acid forms soft pearly-white crystal flakes with a greasy feel. On heating, these crystals lose water at about 100° C. and form metaboric acid.

$$H_3BO_3 = H\,BO_2 + H_2O.$$

Heated to red heat, the metaboric acid forms the anhydride B_2O_3. No intermediate acid, such as pyroboric acid, has ever been isolated, but it might be mentioned that a glassy phase containing less water than the metaboric acid can be obtained, which shows strong fluorescence and afterglow when exposed to short wave ultraviolet light. This fluorescence is caused by traces of organic materials and can be controlled and varied by introducing certain dyestuff or terephtalic acid into the glass.

The atomic structure of H_3BO_3 was the first complete structure of an oxygenic acid which was derived from X-ray patterns. W. H. Zachariasen worked out its crystal structure with the aim to learn something about the role which the hydrogen ions play in crystallized oxygenic acids.

The crystal structure of orthoboric acid can best be described as a pile of two-dimensional lattices each having hexagonal symmetry. The layers are 3.18 A.U. apart, and are held together by very weak forces. This explains directly the perfect cleavage and the low rigidity. Each layer is built up of BO_3 groups which are held together by the hydrogen atoms. The B-O distance is 1.36 A.U. Each hydrogen atom is linked to two oxygen atoms forming collinear groups O-H-O similar to the hydrofluoric ion F-H-F. The presence of O-H-O groups is a characteristic feature of crystalline oxygenic acids and acid salts.

The nature of crystallized H_3BO_3, being a pile of two-dimensional layers explains the plate-like character of the crystals. From the distribution of the surface forces it is to be expected that a crystal grows more rapidly in the direction of the layer than perpendicular to it.

Not until 1937 was B_2O_3 prepared in crystalline form. At this time devitrification of boric oxide glass was first accomplished independently by McCulloch and by Kracek, Morey and Merwin. The reasons for the stability of the vitreous phase and the difficulties in obtaining crystalline B_2O_3 from anhydrous melts shall be discussed later in connection with the atomic structure of the B_2O_3 glass.

L. McCulloch discovered that fused boric acid retaining 8-15% H_2O held for several days (7 to 14 days) at 225-250° C. begins to develop crystals. As the crystallization proceeds the melt loses its water content, sometimes with volcanic violence. By seeding such a liquid, crystallization can be induced to proceed immediately. As the water is being given off, the melt changes into a strong white crystalline solid, and the analysis reveals this to be anhydrous B_2O_3.

Qualitative tests for boric acid are numerous, and one of the most sensitive reactions takes advantage of the volatility of boric acid esters which burn with an intense green flame. This test is based on the reaction of free boric acid with alcohol in the presence of a mineral acid as catalyst (H_2SO_4, HCl).

There is nothing unusual about the esterification of boric acid with monohydric alcohols, such as methyl or ethyl alcohol. It proceeds very slowly, but can be speeded up by catalysis. However, with polyhydric alcohols, such as glycerol, boric acid shows an unusual reactivity which leads to the formation of complex acids being 100 times stronger than the orthoboric acid itself. In its aqueous solutions boric acid is a very weak acid which is only slightly dissociated, probably according to the equation:

$$H_3BO_3 = H_2BO_3^- + H^+$$

The acid is too weak to be titrated as such, but the addition of polyhydric alcohols makes boric acid a strong acid which can be easily titrated. The formation of this strongly acidic complex can be demonstrated by a startling experiment; that is, by pouring together two alkaline solutions one may obtain a mixture which is acid. One prepares a slightly alkaline solution of H_3BO_3 and NaOH using phenolphtalein as an indicator. The other alkaline solution consists of glycerol with a few drops of NaOH and the same indicator. Mixing the two red solutions results in a colorless acid solution containing glyceroboric acid.

2. *Boric oxide in plastics.* The reaction of boric acid with polyhydric alcohols is not only of interest to the analytical chemist, but deserves our attention because some organic derivatives of boric acid may be considered intermediates between inorganic glasses and organic plastics. There are very few bridges between the structure of silicate glasses and that of organic high polymers. Best understood and most thoroughly explored is the field of organic silicones and of the silicic acid esters. Much less is known about the organic tin compounds which, too, can be used to bridge the gap which exists between the ionic structures of glasses and the non-polar organic compounds. Boric acid offers another possibility to bridge the otherwise incompatible structure, a fact which seems to be worthwhile mentioning.

There are several groups of technically important plastics which contain hydroxyl groups on every molecule—cellulose esters or polyvinyl alcohol. E. P. Irany found that in the absence of water these resins react with boric acid in a way that bridges are formed between these long-chain molecules. The action of boric acid on these resins can be compared with the vulcanization or curing of rubber. The cross-linking between the chain-like molecules imparts strength and rigidity to the resin up to the point where it becomes brittle. Unlike the cross-linking in thermosetting plastics or in vulcanized rubber, the change brought about by boric acid is completely reversible on treatment with water. E. P. Irany discovered various uses of this effect, for example, the production of thermoplastic and rubber-like materials in the form of fine powders. We will later, in the discussion of Vycor-glass, cover a similar function of boric acid; namely, its temporary introduction into a substance for changing its working characteristics and subsequent leaching out after this objective has been achieved.

Ordinarily glasses are not soluble in a solvent from which they can be regained in their original structure. The chemical affinity of boric acid to polyhydric alcohols makes it possible, however, to produce soluble glasses. The British Patent 544,734 (March 14, 1941) covers a lead borate glass soluble in such solvents as ethylene glycol, diethylene glycol or glycerine. These solutions have various applications in the electric industry. They

may be used to apply a vitreous enamel to metals on which it may be baked on at 500-550° C.

3. The system B_2O_3 — H_2O. The optical and crystallographic properties, as well as densities of the boric oxide hydrates, were determined by Kracek, Morey and Merwin. These authors found that besides the orthoboric acid H_3BO_3, the sassolite, there exist three modifications of the metaboric acid HBO_2 which stand in monotropic relation to each other. They differ greatly in their chemical reactivity; the densities and refractive indices increase with increasing stability as can be seen from Table III.

TABLE III

Modification	*Melting Point*	*Refractive Index*	*Density*
HBO_2 I	236° C.	1.37 — 1.52	1.78
HBO_2 II	201° C.	1.43 — 1.58	2.04
HBO_2 III	176° C.	1.62	2.48

For the exact optical and crystallographic data the original paper should be consulted. The most instable modification, HBO_2 I, is of particular interest because it is this phase which enhances the nucleation of the anhydride. A mixture of the composition B_2O_3 and H_2O in the molar ratio 1 : 1 heated under the proper conditions will readily form crystallized B_2O_3 if crystals of the HBO_2 I modification were present. In all other experiments in which this modification was totally absent, dehydration resulted in a viscous melt with no crystallization. None of the other two forms of HBO_2 was found to provide suitable nuclei for B_2O_3 crystals. In sealed tubes the authors found that crystallization of B_2O_3 occurred most rapidly when the liquidus temperature for HBO_2 I is just slightly exceeded in the case of solutions somewhat richer in B_2O_3 than the eutectic, so that the crystals of HBO_2 I are melting in the liquid. In open vessels the initiation occurs at these or lower temperatures owing to the continuous dehydration of the melt and the tendency toward dissociation of the HBO_2 I phase. Once crystallization is initiated by seeding or by the presence of HBO_2 I the rate of crystallization is relatively high for the more fluid compositions near HBO_2. The structural changes which accompany further dehydration and are responsible for the tremendous increase of viscosity are also responsible for the reluctancy of these melts to crystalize. Once the crystalline B_2O_3 was available, melting point data could be obtained. Previous to this work no reliable melting point data of B_2O_3 were available. Kracek, Morey and Merwin give 450° ± 2° C. and McCulloch found a somewhat higher value (460° C.).

The invariant points of the system H_2O — B_2O_3 as well as the relative vapor pressures based on the data of Kracek, Morey and Merwin are given in Table IV.*

To the glass technologist, the system B_2O_3 — H_2O is of more than academic interest. Previously it was mentioned that the boric acid and the borates found in various deposits came to the surface of the earth in the form of H_3BO_3 which is volatile with water vapor. The volatility of B_2O_3 is of primary interest for glass melting in both laboratory and plant scale. The volatility might change the composition of the glass, especially its surface

TABLE IV

Phase Reaction	*Mol % B_2O_3*	*Temp. ° C.*	*p/p_o*
Melting Point of Ice	0.0	0.0	1.0
Eutectic ice + H_3BO_3	0.333	—0.76	0.994
Melting Point of H_3BO_3 ..	25.0	170.9	0.448
Incongruent melting of H_3BO_3	21	169	0.523
Eutectic H_3BO_3 + HBO_2 II	29.3	169.6	0.373
Eutectic H_3BO_3 + HBO_2 III	38	158.5	0.342
Melting of HBO_2 I	50	236	0.101
Melting of HBO_2 II	50	200.9	0.101
Melting of HBO_2 III	50	176.0	0.101
Eutectic HBO_2 I + B_2O_3	50	176.0	0.101
Eutectic HBO_2 II + B_2O_3	51.8	200.5	0.086
Eutectic HBO_2 III + B_2O_3	55.1	235	0.063
Melting of B_2O_3	100	450±2	0.000

layer, but it also provides a means for changing the glass surface through its exposure to B_2O_3 containing gases.

Since the experiments of P. Tschijewski it is an established fact that pure B_2O_3 is not volatile in dry air. The most volatile molecule is H_2BO_3 the orthoboric acid. The experiments of S. Bezzi, M. v. Stackelberg, F. Quatram and J. Dressel, as well as the crystal structure of H_3BO_3 as determined by W. H. Zachariasen have contributed much to our understanding of the problem. A. Thiel and H. Siebeneck interpreted their results by assuming a hydrate $H_3BO_3 \cdot 2\,H_2O$ to be the volatile constituent of the B_2O_3 — H_2O vapors.

Geochemists will be particularly interested in the solubility of boric acid in H_2O at high temperatures and pressures. Glass technologists are more concerned with the volatility of boric acid with water under atmospheric pressure and in the rate of obtaining equilibrium if steam is passed over boric acid.

C. F. Spiess, a collaborator of M. v. Stackelberg, examined the volatility of boric acid with steam between 109 and 180° C. under atmospheric pressure. Table V gives the concentration of boric acid in the vapor (millimol per liter) and the partial pressure of boric acid in the vapor phase (mm) for several temperatures.

TABLE V.

Conc. H_3BO_3			Conc. H_3BO_3		
t° C′	in liter	$p_{H_3BO_3}$ mm.	t° C′	in liter	$p_{H_3BO_3}$ mm.
109	0.026	0.62	149	0.310	8.10
119	0.054	1.31	157.5	0.368	9.80
129	0.108	2.70	158.8	0.327	8.67
134	0.171	4.30	159.2	0.332	8.87
138.5	0.237	6.03	160	0.350	9.37
140	0.245	6.25	167	0.44	12.0
142	0.246	6.30	169.8	0.45	12.4
145	0.249	6.44	180	0.53	15.0

The logarithms of the $p_{H_3BO_3}$ values plotted against the reciprocal absolute temperature were found to lie on two straight lines intersecting near 140°C. Evaluation of these relations as well as of the volatility of boric acid at different pressures led to the conclusion that it is preponder-

*Note: Because phase diagrams are now easily available in the excellent compilation of "Phase Diagrams for Ceramist" by F. P. Hall and Herbert Insley, no effort has been made to reproduce the diagrams of B_2O_3 with H_2O and other oxides.

antly the $B(OH)_3$ molecule which is present in the vapor phase. The HBO_2 molecule is much less volatile and the anhydride B_2O_3 has no measurable vapor pressure.

In order to find out whether or not the results of the distillation experiments corresponded to equilibrium conditions the authors changed the speed of distillation over a wide range. Their findings are noteworthy. In the low temperature region (110°C.) even the highest speed of distillation (4g H_2O vapor/minute) indicated complete saturation. With increasing temperature, however, saturation required more time. At 170°C., for example, 0.3g H_2O vapor/minute was found to be too fast for establishing equilibrium. For these temperatures the equilibrium conditions were calculated from several speeds by extrapolation for infinitely slow distillation speed.

The behavior of the boric acids in respect to their volatility in the presence of water vapor can now be fully understood from the atomic structure of these compounds. According to W. H. Zachariasen, the crystallized orthoboric acid consists of $B(OH)_3$ molecules forming planes which are held together by relatively weak forces. Within the planes the molecules are bonded by hydrogen bonds. This type of structure makes it understandable why $B(OH)_3$ is volatile and why the speed of saturation is so high. It is typical for hydrogen bonds that due to their low activation energy bonds are easily formed and easily broken. From a crystalchemical point of view $B(OH)_3$ resemble BF_3 which even at room temperature is a gas. From Raman spectra of boric acid and sodium borates in aqueous solutions, J. H. Hibben concluded that this atomic configuration exists also in solutions. The most probable structure corresponds to a plane equilateral triangle, the oxygen atoms being located at the corners and the boron atoms at the center of the plane.

The structures of metaborates point toward chains. It is probable that the vapors of $B_2O_3 - H_2O$ mixture contain some molecules having the structure $(OH)_2 \cdot B - O - B \cdot (OH)_2$ which corresponds to two triangles with a common corner. Also, this compound should have a noticeable vapor pressure, but as it has to form from the solid phases by an atomic rearrangement, it is understandable that the rate of establishing vapor pressure equilibrium will be slow.

Which conclusions can be drawn from these purely structural interpretations? In order to introduce boric oxide into the glass batch and avoid unnecessary loss through volatilization, it should not be used as sassolite H_3BO_3, but as a borate or as an anhydride. Furthermore, the rate of heating the glass batch should be as high as possible, at least in its initial stage. Materials which contain water of crystallization should be avoided in the glass batch containing boric acid. Water vapor delays dissociation of the volatile boric acids, and thus enhances loss of B_2O_3.

4. Some Reactions of the Boron Trifluoride. Speaking of the volatility of boron compounds, attention shall be directed to a number of interesting reactions which one day might find application for surface treatment of silicate glasses or for removing oxides from fluoride melts. In melting certain low refractive index glasses derived from beryllium fluoride traces of water were found to interfere with the transparency of the glass because hydrolysis leads to the formation of metal oxides which are insoluble in many fluoride melts. In order to convert these oxides into fluorides a reaction might be useful which was discovered by P. Baumgarten and W. Bruns. They found gaseous boron fluoride BF_3 to react with oxides, borates, silicates and other oxygen-containing salts under formation of fluorides and a volatile compound, probably the boron oxyfluoride $(BOF)_3$.

$$3\,MgO + 3\,BF_3 = 3\,MgF_2 + (BOF)_3$$
$$Al_2O_3 + 3\,BF_3 = 2\,AlF_3 + (BOF)_3$$
$$3\,SiO_2 + 6\,BF_3 = 3\,SiF_4 + 2(BOF)_3$$
$$3\,TiO_2 + 6\,BF_3 = 3\,TiF_4 + 2(BOF)_3$$
$$Ca\,SiO_3 + 3\,BF_3 = CaF_2 + SiF_4 + (BOF)_3$$

The application of these reactions to silicate-chemical problems, surface treatment of glasses and the conversion of oxides into fluorides, deserves further study.

5. Compounds of B_2O_3 with metal oxides. In the middle of the past century the mineralogists in France became interested in the synthesis of minerals from the oxides. The reaction between solid phases in most cases did not lead to well crystallized products and as they depended on the use of the microscope which requires crystals of a fairly good size, experiments were undertaken to enhance crystal growth through "agents minéralisateures" or mineralizers. Boric oxide was found to meet these requirements. Many minerals could be obtained in good crystals by fusion of the oxides with B_2O_3 and later dissolving the fluxing agent. This method and several applications were described by J. J. Ebelmen (1848). In connection with the synthesis of minerals several borates were discovered, and their optical properties were described. (Ebelmen, Le Chatelier, Mallard)

But it was not before the beginning of this century (1904) that W. Guertler made a more systematic survey over the behavior of metal oxides towards fused boric acid. This work done in the laboratory of G. Tammann must be considered scouting work, and many of the results had to be revised. Nevertheless, it was the basis for further studies and makes us familiar with the fundamental principles. Here the phenomenon of immiscibility of fused oxides was first encountered and examined; more than 20 years before the same phenomenon was found to occur in certain silicate melts. (J. W. Greig, 1927)

With respect to their behavior towards B_2O_3, W. Guertler divided the oxides into three groups:

I Group. The oxides of the alkali metals, thallous and silver oxide. They form clear melts when fused with B_2O_3 in the ratio 1:1 or more boric acid. The melts with higher B_2O_3 content form clear glasses on cooling.

II Group. Mixtures from pure B_2O_3 to the molar ratio 1:1 form homogeneous melts at high temperature, but on cooling—within a certain composition region—the melt becomes turbid and segregates into two liquid phases immediately. PbO, Bi_2O_3, As_2O_3, TiO_2 belong to this group.

III Group. With some oxides no homogeneous melts could be obtained even if they were heated to 1400°C. with an excess of boric oxide: CaO, SrO, BaO, MgO, ZnO, CdO, CoO, NiO, FeO and the oxides of the rare earths.

As mentioned before, this work is not more than a scouting over the whole field, and the results are not very reliable because at this time the workers were not yet familiar with the slow rate of these reactions. Guertler,

(*Continued on page* 156)

ECONOMIC PROBLEMS IN THE USE OF ALTERNATE FUELS

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I. Introduction

Glass plants for many years have sought locations where an abundant supply of inexpensive fuel would be available for their use. In the early days, plants were located adjacent to wood, coal or gas fields. Today, marketing costs of finished ware often offset any advantages offered by low cost fuel sites. This paper will concern itself with fuel costs only.

The tremendous quantities of fuel consumed by the glass industry are utilized for the development of power, light and for melting and processing heat. Consideration will be given to the use of fuel for melting and processing only. It will be assumed that power and light are purchased or plant generated and made available at a fixed cost per KWH.

II. Fuel Classifications

Fuels may be broadly classified into two categories. a) *Bulk Heating:* Such as large furnaces or boilers which comprise large combustion chambers in which large quantities of fuel are consumed. Such applications are ideal for the use of producer gas and heavy oil firing. b) *Confined Heating:* Such as feeder forehearths, annealing lehrs, ovens and furnaces in which confined combustion chambers are used and accurate automatically controlled temperature conditions are desirable. It is in installations of this kind that natural gas, coke oven gas, propane and vapofied kerosene are ideal fuels.

III. Indeterminates

It should be kept in mind that even though certain fuels may figure to be the lowest in BTU cost, the ultimate fuel selected in confined heating applications may not be the lowest in BTU cost. The end result of better control, quality of product and increased production may offset the higher cost per BTU.

This paper will limit itself to a consideration of BTU costs only.

In addition to the above is the effect of various types of fuels on the life, maintenance and repair costs of the furnace structures. This is a subject for a special paper and will require a study of considerable plant operating data. General plant experience places the various fuels in the following order as far as furnace life is concerned. Producer gas is considered to be the least destructive of all the fuels. 1) Producer gas; 2) Propane or butane; 3) Natural gas; 4) Coke oven gas; and 5) Fuel oil.

IV. Consideration of BTU Costs

A consideration of BTU costs involves careful consideration of the following items, all of which will be considered in this paper: a) Basic fuel cost; b) Fuel handling cost; c) Fuel processing cost; d) Investment handicap; e) Furnace structural cost incidental to burning a specific fuel; and f) Burning efficiency of the fuel.

The item of investment deals with the cost of the fuel system which is rather flexible in the case of most fuels. Small installations in most cases represent the greatest capital investment per unit of fuel requirement.

All fuels except producer gas can be utilized with only minor furnace design changes.

Producer gas fuel vitally affects furnace design and cost. Because of the high cost and broad capacity increments, each producer gas installation must be given special considerations. Several specific examples will be cited to point out the extreme care that is required to make accurate fuel cost comparisons.

V. Object of This Paper

The object of this paper is to present a comprehensive outline of the various costs that must be considered to permit a BTU cost evaluation to be made of various kinds of fuels. A figure will be introduced that has been termed "Investment Handicap." This figure charges against a specific fuel an amount to cover interest on that portion of the cost of the fuel system and furnace structural cost that is in excess of the cost of a natural gas fired installation.

VI. General Fuel Characteristics

In order to make an intelligent appraisal of costs, care must be taken that fuels that are to be compared have the proper characteristics. The following tabulation, Figure I, prepared by the Phillips Petroleum Company, shows the cost of Propane in various localities in the United States and equivalent costs of Coke Oven and Natural Gas based on a straight BTU basis.

FIGURE I.
REPRESENTATIVE RATE
PROPANE COSTS

Location	Rate Per Cwt. (cents)	Rate per Gallon (cents)	Fuel Cost Per Gallon (cents)	Delivery Cost (cents)	Equiv. to 530 BTU Gas (cents)	Equiv. to Natural Gas 1000 BTU
Hartford, Conn.	91	6.186	4.0	10.186	58.8	$1.108
Waterbury, Conn.	91	6.186	4.0	10.186	58.8	1.108
Wilmington, Del.	85	5.778	4.0	9.778	56.4	1.064
Miami, Fla.	100	6.798	4.0	10.798	62.4	1.176
Atlanta, Ga.	71	4.827	4.0	8.827	50.9	0.961
Chicago, Ill.	42	2.855	4.0	6.855	39.6	0.746
Ft. Wayne, Ind.	50	3.399	4.0	7.399	42.7	0.805
Indianapolis, Ind.	44	2.991	4.0	6.991	40.4	0.761
Davenport, Iowa	39	2.651	4.0	6.651	38.4	0.724
Boston, Mass.	91	6.186	4.0	10.186	58.8	1.108
Detroit, Mich.	39	2.651	4.0	6.651	38.4	0.724
Minneapolis, Minn.	43	2.923	4.0	6.923	40.0	0.754
Kansas City, Mo.	26	1.764	4.0	5.764	33.2	0.627
Salem, N. J.	87	5.914	4.0	9.914	57.2	1.080
Cleveland, Ohio	70	4.759	4.0	8.759	50.6	0.954
Philadelphia, Pa.	85	5.778	4.0	9.778	56.4	1.064

Presented before the Ninth Conference on Glass Problems, University of Illinois, Urbana, Ill.

VII. Fuel Specifications

Having located a coal supply, the next question is its suitability for use in a gas producer. The following general specifications can be used as a guide.

The Volatile content of coal for producer gas use should not exceed the fixed carbon content. High sulphur and low fusion ash are objectionable. The fusion point of the ash should not be less than 2,200° F. Volatile matter in excess of 42% is not desirable. Ash in excess of 8% is burdensome. Do not use coal if ash is in excess of 10%.

FIGURE II.
IDEAL COAL ANALYSIS
(Keystone Coal Buyers Manual 1937)

	Ideal	Average of 80 Good Coals	Representative Non-Coking Appalachian Coal with High Fusion Ash
Moisture %	2.0	3.6	7.5
Volatile matter	36.0	35.6	32.5
Fixed Carbon	56.0	54.6	57.0
Ash	6.0	6.3	3.0
Sulphur	1.0	1.0	0.8
Fuel Ratio (Fixed Carbon to Volatile)	1.56	1.53	1.75
BTU per pound	14,000	13,540	12,500
Softening point of ash °F.	2,600	2,460	——

FIGURE III.
FUEL OIL SPECIFICATIONS
(CS/2-33 U. S. Fuel Oil Specs.)

Oil	Maximum Sulphur	Water & Sediment	Average Heating Value @ 60° F. Per Gallon	Average Preheat Required
1	0.5	0.5	134,000	None
2	0.5	0.5	137,000	None
3	.75	0.1	141,000	None
4	1.25	1.0	145,000	145° F.
5	No limit	1.0	149,000	170° F.
6	No limit	.025 Sediment	154,000	200° F.

Total Sediment and Water in #6 oil shall not exceed 2%, Oil expands approximately 3½% per 100° F. rise in temperature above 60° F.

Gaseous fuels such as natural gas and coke oven gas usually have a fixed and uniform heating value.

Both fuels should have low sulphur contents if sulphur bloom on the processed material is objectionable.

Both fuels will have their value enhanced through the presence of lighter hydrocarbons, such as C_2H_4 and C_2H_6 which enhances the emissivity of the flame.

Propane and Butane produce flames with high emissivity and because of their cleanliness are ideal fuels for all types of heating applications.

VIII. Fuel Handling and Preparation

All fuels other than natural gas and coke oven gas require special handling and auxiliary equipment to insure good combustion conditions. Such items as unloading, pumping and atomization costs will be analyzed.

Throughout this paper, all figures on producer gas operation will be based on the following basic figures shown in Figure IV.

The cost of a steam generating plant and the cost of producing steam for a producer gas plant is included in the figures covering the operation of the producer plant. When steam is required in smaller quantities for use in providing heat to preheat fuel oil or for oil atomization, the requirements are figured as being supplied by a smaller automatic boiler installation. The cost of generating steam in such a plant and the plant investment is tabulated in Figure V.

FIGURE IV.
PRODUCER GAS—HEAT AVAILABILITY

Gas Coal BTU per pound	13450
Gas @ 60° F. per pound of coal in cubic feet	66.8
Specific heat of gas per cubic foot @ 60° F.	.01768
Average heating value of 1200° F. hot gas per cubic foot @ 60° F. base	163 BTU
Average heating value of 120° F. washed gas per cubic foot @ 60° F. base	144 BTU
Loss due to washing	11.65%
Gain through regeneration 1200° to 1800° F.	10.6 BTU
Available heat in 1800° F. gas per cubic foot @ 60° F.	173.6 BTU
Available heat in washed gas preheated to 720° F...	154.6 BTU
Steam coal per pound of producer coal	.062 lb.

*Washed gas preheated from 120° to 720° F. requires the same number of BTU's per cubic foot @ 60° F. base temperature as hot gas preheated from 1200° to 1800° F.

FIGURE V.
AUTOMATIC STEAM BOILER PLANT

Steam generated per 24 hours		66240#
Boiler Horsepower		80
Pressure		125 p.s.i.
Fuel Oil per gallon		6 cents
Investment:		
Boiler	$7,570.00	
Softener	1,200.00	
Installation	750.00	
Floor Space	1,500.00	
Total		$11,020.00
Factor of evaporation using 160 F. water		1.093
Factor of evaporation using 70° F. water		1.1184
Operation Cost:		
3 hour attendance @ $1.25		$ 3.75
Repairs $1.50 per HP per year		.33
Depreciation 5%		1.51
Oil cost based on 8 gallons per 1,000# of steam and using 160° F. water		34.75
Total cost per 24 hours		40.34
Cost per M lbs. of steam		.61

The average steam requirements per gallon of fuel oil having a density of 7.243 pounds per gallon is as follows. These figures are average and should not be used to figure the maximum demand or boiler capacity.

Steam for unloading per gallon of oil	.20#
Steam for atomization	4.50
Steam for heating oil	1.50
Total steam per gallon of oil	6.20#
Total steam per pound of oil	.856#
Atomization steam per pound of oil	.621#
Unloading and preheating steam per pound of oil	.235

Cost of Unloading and Pumping Oil

15 HP @ $.012 per KW hr. Unloading	$.01492
5 HP @ $.012 per KW hr. Pumping	.00895
Unload Labor @ $1.25 per hour	.34733
Pumping Labor @ $1.25 per hour	.2500
Total Cost per Thousand Gallons of Oil	$.6212

The cost of producing compressed air for oil atomization requirements will be based on a typical medium sized compressor plant, assuming power to be available at $.012 per KWH. The cost of producing compressed air is shown in Figure VI.

To calculate compressor capacity *12.5 cubic feet* of air should be provided for each pound of oil that is to be

FIGURE VI.
COMPRESSOR PLANT

Capacity		425 CFM
Pressure		45 p.s.i.
Motor Horsepower		75
Power Cost per KWH		$.012
Investment:		
Compressor, motor starter, tank and aftercooler	$4,600.00	
Foundation	700.00	
Installation	500.00	
Piping, etc.	3,500.00	
Total		$9,300.00
Operation Cost:		
3 hours Attendance @ $1.25		$ 3.75
Power		16.10
Lubricant $3.75 per M cubic feet cap. per min./mo...		.053
Fixed Charges 15%		3.82
Total Cost per 24 hours		23.723
Cost per M cubic feet of air		3.87¢

atomized. This allowance will provide sufficient air for cooling of burner tips.

When Propane or Butane are used as fuels, suitable storage tanks, unloading pumps and vaporizing equipment must be provided. The following basic figures cover the cost of unloading and installation costs.

FIGURE VII.
PROPANE HANDLING COST

Unloading Cost based on 9,600 gallons

Car unloaded in 5 hours—Labor	$5.00
Power—5 HP @ $.012 per KWH	.224
Steam for vaporization 9,600 gallons at 1.25# per gallon @ 61 cents	7.31
Total Steam Cost per gallon	.000762
Total Labor and Power Cost per gallon	.000544

FIGURE VIII.
PROPANE INSTALLATION COST

Cost per gross gallon of storage

Undiluted system including storage tank, accessories, unloading equipment, vaporizing unit and regulators	$ .42
Low pressure system involving diluters, etc., to substitute for city or natural gas	.48
High pressure system and diluter	.54
Extra 30,000 gallon storage tank	10,000.00

The above costs are based on gross gallons of storage capacity. A 30,000 gallon tank should not be filled in excess of 25,000 gallons.

IX. Net Heating Values

In order to evaluate fuels on a straight BTU basis, it is necessary to give consideration to the reduction in useful heat resulting when steam is used as an atomizing medium for oil. The following calculation based on the use of .621 pounds of steam per pound of oil is representative of most fuel oils.

Products of combustion per pound of oil:

H_2O	1.183
CO_2	3.158
SO_2	.0044
N_2	11.010

Loss to water vapor (152 plus 970.3) 1.183=1327.6 BTU

In order to simplify computations, we will assume an average stack temperature of 1000° F. Using steam for atomization effects a loss of approximately 1¼% of the high heating value of the fuel at a stack temperature of 1,000° F.

Atomizing steam .621 x .478 (1,000—212)=233.8 BTU
Total loss to water vapor per pound of oil=1561.4 BTU

All gaseous and liquid fuels during combustion suffer a loss in heating value through the formation of water vapor. This is true of most sources of heat with the exception of that supplied by electricity, which is available without loss at 3,412 BTU per KW hr.

Figure IX is a compilation showing the net heating value of various fuels under various methods of use. In addition to indicating the gross and net heating values, the net heating value is expressed in percentage of the gross value and the quantity of fuel required to produce one million net BTU's has been tabulated.

FIGURE IX.
NET HEATING VALUES

Fuel	Gross BTU/ cu. ft. @ 60° F.	Net BTU/ cu.ft. @ 60° F.	Net Heat % of gross	One Million Net BTU'S
Coke oven gas	520	466	89.6	2,146 C.F.
Natural gas	1,002	904	90.2	1,106 C.F.
Propane	2,504	2,316	92.2	11.93 Gal.
Refiners gas	1,650	1,524	92.5	656 C.F.
Butane	3,184	2,935	92.0	10.83 Gal.
Kerosene—gallon vapofied.	135,000	125,685	93.1	7.95 Gal.
Heavy oil—air atomize....	150,000	139,380	92.8	7.18 Gal.
Heavy oil—steam atomize..	150,000	137,509	91.7	7.28 Gal.
Light oil—air atomize.....	141,000	131,378	93.18	7.61 Gal.
Light oil—steam atomize..	141,000	129,696	91.9	7.81 Gal.
Galusha coke gas.....	137	132	96.2	1,575 C.F. 94.7 lb.
Cold producer gas—120° F.	144	133	92.5	112.5 lb. coal
Cold producer gas—720° F.	154.6	144.6	93.5	103.5 lb. coal
Hot producer gas—1,200° F.	163	153	93.9	97.8 lb. coal
Hot producer gas—1,800° F.	173.6	163.6	94.2	91.5 lb. coal
Electricity KWH	3,412	3,412	100	293 KW

Steam coal per pound of producer coal—.062 lb.
Producer gas—66.8 cu. ft. @ 60° F. per lb. of coal.
Galusha gas—80 cu. ft. @ 60° F. per lb. of coke.
Propane—91,800 BTU per gal. or 36.18 cu. ft. @ 60° F.
Butane—102,600 BTU per gal. or 31.46 cu. ft. @ 60° F.
Coal—13,480 BTU per lb.
Light oil—7.24 lbs. per gal.
Heavy oil—8 lbs. per gal.

X. Fuel Burning Efficiency

The quantity of fuel required to produce 1,000,000 Net BTU's, as tabulated in Figure IX, does not take into consideration the burning efficiency of the fuel. Quantities shown in Figure IX must be increased to compensate for the stack loss of each respective fuel. Inasmuch as no products of combustion result when electric heat is used, no correction factor need be applied. Figure X shows a set of burning efficiency curves for various fuels. These curves indicate the per cent of the lower heating value of each fuel that is lost when operating at different stack temperatures.

Because of the low calorific value of producer gas it is usually preheated in a regenerator. Regenerative furnaces must be reversed, resulting in a loss of producer gas equal to the volume of the gas uptake, gas regenerator and flue connecting the regenerator to the gas reversing valve. Based on a 30 minute reversal cycle this loss approximates 1% of the fuel input to the furnace. In the final evaluation of the various fuels, this loss must be reckoned with if the producer gas is regenerated.

Recently great interest has been shown in the use of

commercial oxygen rather than air with its accompanying nitrogen load.

The major steel producers already have such installations producing steel and iron. The advantages are: a) High temperatures; b) Smaller furnace structures; c) Lower radiation loss; d) Greater furnace output; and e) Reduction in stack losses due to elimination of oxygen ordinarily introduced with the combustion air.

In open hearth melting, approximately 3¾% of the total oxygen requirements are introduced in concentrated form.

Assuming that the only saving resulting from the use of commercial oxygen rather than air for combustion, would be a saving in stack losses, a hypothetical case will be considered in an effort to determine just how much could be paid for oxygen.

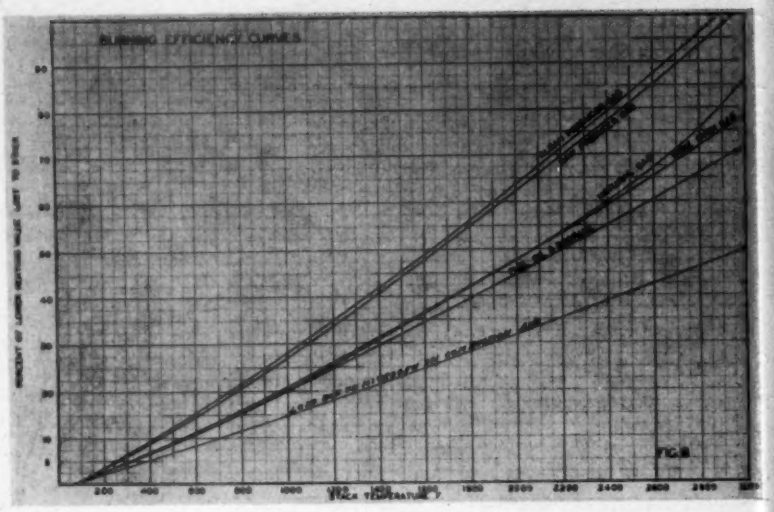


Fig. 10

Reference to Figure X shows a curve indicating the stack loss due to nitrogen introduced with the combustion air. This curve has been calculated for natural gas combustion, but is fairly accurate for most fuels other than producer gas.

Hypothetical Case

Natural Gas	High Heating Value.....	1,047 BTU/cu.ft. @ 60°
	Low Heating Value.....	946 BTU/cu.ft. @ 60°
Air per cu. ft. of gas @ 60°.....		10.04 cu. ft.
Nitrogen in air		7.98 cu. ft.
Oxygen in air		2.06 cu. ft.
Assumed cost of natural gas per million BTU's		35¢
Assumed cost of Oxygen per ton.....		$2.00
Oxygen required per million BTU of gas		184.3 lbs.
Cost of Oxygen		$ .1843
Stack loss at 1,000° F. from Fig. 10....		20%
Stack loss to N_2 at 1,000 °F. from Fig. 10		15%
Value of natural gas loss due to N_2.....		5.25 Cents

It is evident from the above that with fuel at 35¢ per million BTU, the loss due to nitrogen introduced with the combustion air is approximately 5.25 cents when the stack gases leave at 1,000°F. To eliminate the loss due to nitrogen by eliminating, it would require the expenditure of 18.43 cents for oxygen. Obviously, the real benefits from the use of commercial oxygen in place of air for combustion results in great measure from the various other advantages enumerated, plus that effected through an almost complete elimination of excess air.

XI. Fuel Requirements

In order to study the economies of using various kinds of fuels, three glass melting furnace installations will be placed on a comparative basis. Each installation must be given detailed consideration from the standpoint of labor, power, burning efficiency and capital investment.

The three installations to be considered are: a) 2—100 Ton Furnace Plant; b) 2—55 Ton Furnace Plant; and c) 1—55 Ton Furnace Plant.

The first consideration is the determination of the fuel input required for each installation and shown in Figure XI.

XII. Coal Gasification Cost

Based on the fuel requirements shown in Figure XI, the three proposed plants to be considered as listed under "FUEL REQUIREMENTS," will be equipped with the following producer gas equipment. The tabulation also indicates the percentage of maximum capacity at which the producers are operating.

	Furnace	Producers	Producer Capacity
a)	2—100 T.	2—10 ft.	61.5%
b)	2— 55 T.	1—10 ft.	71.9%
c)	1— 55 T.	1— 8 ft.	59.8%

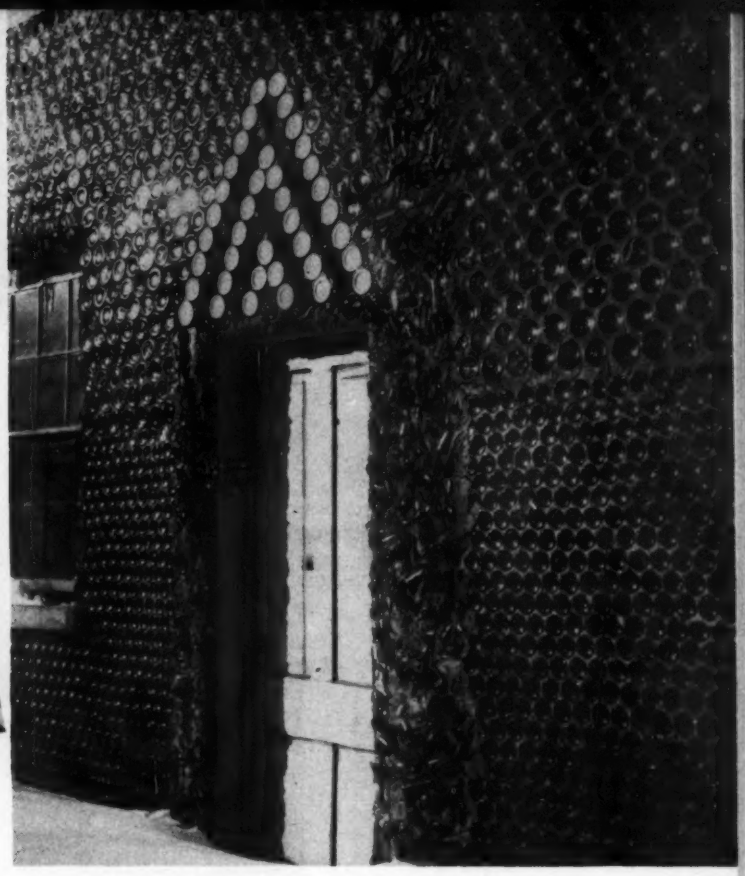
Figure XII is a tabulation of the producer operating costs of the three proposed plants. In each case a gasi-

(*Continued on page* 160)

FIGURE XI.
FUEL REQUIREMENTS

	1—100 Ton Furnace 18 x 32		1—55 Ton Furnace 16 x 22	
Total net heat input per 24 hours.....	768,400,000 BTU		447,480,000 BTU	
Hot producer gas—1200° F.....	5,022,000 BTU	35.9 T. Coal	2,924,000 BTU	21.8 T. Coal
Hot Producer gas—1800° F.....	4,696,000 BTU	35.15 T. Coal	2,735,000 BTU	20.5 T. Coal
Washed producer gas—120° F.....	5,770,000 BTU	43.18 T. Coal	3,364,000 BTU	25.1 T. Coal
Washed producer gas—720° F.....	5,314,000 BTU	39.77 T. Coal	3,094,000 BTU	23.1 T. Coal
Light oil—air atomize		5.848 Gallon		3330 Gallon
Light oil—steam atomize		5930 Gallon		3450 Gallon
Heavy oil—air atomize		5510 Gallon		3210 Gallon
Heavy oil—steam atomize		5590 Gallon		3250 Gallon
Natural Gas		850,000 C. F.		495,000 C. F.
Coke Oven Gas		1,648,900 C. F.		960,240 C. F.
Propane	331,700 C. F.	9168 Gallon	193,200 C. F.	5341 Gallon
Butane	216,800 C. F.	8321 Gallon	152,400 C.F.	4844 Gallon

*Washed producer gas preheated from 120 to 720° F. requires the same number of BTU's per cubic foot @ 60° F. base temperature as Hot gas preheated from 1200 to 1800° F.



PRECURSOR OF THE GLASS BLOCK OR BOTTLE YOUR OWN BUILDING

By H. M. CLOUTIER

With ingenuity, resourcefulness and a flair for building, Patrick "Moon" Mullins created one of the most interesting buildings in the city of Escanaba, Mich.

In 1935, before small town people were completely aware of the new trend in glass walls, glass blocks, etc., eighteen year old Pat Mullins Jr., was faced with a problem.

He had been driving trucks for a local contractor and one day the contractor said, "Pat, we have to clean up that mess of bottles out at the old brewery. Hop to it."

So Pat, or Moon as he was nicknamed, drove out to the brewery. He had the job of carting this huge pile of 60,000 bottles out to the city dump. He surveyed the job before him. It really was a shame to throw all those good bottles away, he thought to himself.

Suddenly he had an idea. Why couldn't he use them to build himself a garage? He was an all round handyman, general auto mechanic, carpenter, plumber and electrical man—it might be possible.

So, instead of taking the bottles to the city dump, this huge pile was transferred to his back yard.

Then began the long task of sorting and planning. He scouted for other material he could use. There could be no new material in the building for he hadn't much spending money.

Stones for the foundation came from the Escanaba River, near the paper mill, where the rock was hard and could be chiseled out in layers. Brick for the corners came from the old Cleveland Cliff Charcoal Kilns at Kipling, long defunct.

Concrete to make the garage floor was carefully gathered from spillings from the huge trucks on their way to paving operations on 23rd Street.

He salvaged lumber and old windows from the ancient and dilapidated grain elevators at Gladstone. Only one thing was left to buy. One ton of lime for mortar.

The foundation was 24 by 36 feet. On the flat stones from the river went a double row of one-half pint bottles placed neck to neck and stuck together with mortar. Then came a six foot wall of half pints and from there to a height of fourteen feet, were 28,000 family quarts and porter bottles.

In the front of the garage, Moon made a neon-like sign across the top of the building by breaking off the necks of amber and green bottles. With lights behind it, it read, "PATS MOTOR SERVICE".

He finished around the outside of the windows with small bits and pieces of colored bottles. He built the large garage doors from scraps of lumber and did all his own wiring and plumbing.

The garage was finished roughly in December 1936 when Pat was nineteen years old. It was entirely finished in the summer of 1937. He built it alone, without any help and in his spare time.

CONVECTION CURRENTS IN A GLASS TANK

By IVAN PEYCHÈS, Sc.D.
Director of Research in the Glass Factories of the *Compagnie de Saint-Gobain*

TRANSLATED FROM THE BULLETIN DE L'INSTITUT DU VERRE (PARIS) FOR JUNE, 1947

By LOIS SUTTON and S. R. SCHOLES

PART III

The Elementary Theory of Convection Movements

A.—*Theory of an ideal bath.*

a. *Production of thermal currents.* Let us consider two receptacles A and B, containing the same liquid of specific gravity ρ_0 at the reference temperature θ_0. Let us raise the liquid contained in A to the temperature θ_1; its specific gravity becomes:

$$(1) \quad \rho_1 = \rho_0 \, [1 - k \, (\theta_1 - \theta_0)]$$

(k = coefficient of cubical expansion of the liquid.)

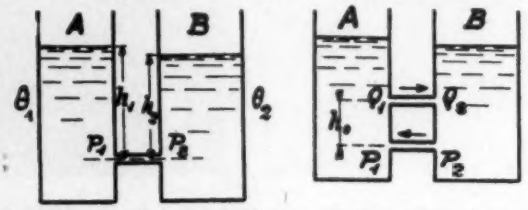


Fig. 25 a and b. Establishment of Convection Currents.

Let us raise the same liquid contained in B to the temperature: θ_2; $(\theta_1 > \theta_2)$; its specific gravity becomes:

$$(2) \quad \rho_2 = \rho_0[1 - k \, (\theta_2 - \theta_0)]$$

Let us now establish a communication between A and B by a horizontal conductor P_1P_2 (Figure 25-a). There is equilibrium only if the pressures in P_1 and P_2 are equal which is written as follows:

$$(3) \quad \rho_1 h_1 = \rho_2 h_2$$

Next, lét us establish a second communication Q_1Q_2 at a level higher than h_0 to the level of P_1P_2 (Figure 25 b).

The pressures on Q_1 and Q_2 are, respectively:

$$(4) \quad (4') \quad \rho_1 g \, (h_1 - h_0) \text{ and } \rho_2 g \, (h_2 - h_0)$$

Equilibrium could exist only if the equality (4)=(4') were satisfied at the same time as the equality (3). For this, there must be simultaneous equations, $\rho_1 = \rho_2$ and $h_1 = h_2$ which, following the relations (1) and (2), can be produced only when $\theta_1 = \theta_2$.

If we maintain, then, the difference of temperature $\theta_1 - \theta_2$, the pressure is stronger in Q_1 and the liquid flows from A to B. Following this, the pressure in P_2 becomes higher than that of P_1, and in the conductor P_1P_2 the liquid flows from B to A. A permanent routine is established in the clockwise direction (in the figure) and it is there that we find the first cause of the observed movements in the glass tank. The preceding reasonings are valid if the conductors P_1P_2 and Q_1Q_2 are replaced by a canal of h_0 height. Thus, there is a tank whose two compartments would be connected by a throat, or would be separated by a barrier (Figure 26).*

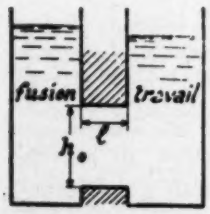


Fig. 26.
Passage: the throat.
fusion: melting.
travail: working.

The dynamic pressure is deduced from relation (4) — (4'), admitting the equality (3). It is equal to:

$$(5) \quad P_0 = \rho_0 gk \, (\theta_1 - \theta_2) \, h_0$$

In order to keep an account of the conservation of the flows, we break down this pressure into two equal pressures, one directed from A toward B in the higher portion of the canal, the other directed from B toward A in the lower portion of the canal. The curve of the pressures following the height of the canal is represented on Figure 27(a); it responds to the equation:

$$(6) \quad H = \rho_0 gk \, (\theta_1 - \theta_2) \, y = Ky, \text{ y varying from } + \frac{h_0}{2} \text{ to } - \frac{h_0}{2}$$

b. *Calculation of speeds in a throat or under a barrier.* In order to calculate the speed of the flowing liquid, it is assumed that the width of the canal is large compared with its height. Thus, the only intervening friction will be that on the upper and lower walls of the throat and not that on the lateral walls.

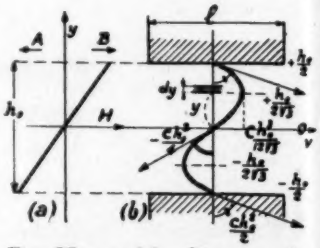


Fig. 27 a and b. Currents of a throat.

The retarding force which acts upon a layer of thickness dy, of surface S, situated at the ordinate y, is:

$$(7) \quad df = \eta S \frac{d^2v}{dy^2} \, dy$$

It is compensated by the pressure which acts on the considered edge. The equation which is involved only in a throat (S = 1), per centimeter of width, is as follows:

$$(8) \quad \eta l \frac{d^2v}{dy^2} \, dy = Kydy$$

Conditions being taken into account, the integration of this equation to the limits v = 0 for y = 0 and $y = \pm \frac{h_0}{2}$ leads to:

$$(9) \quad v = \frac{\rho_0 gk}{6\eta} \cdot \frac{\theta_1 - \theta_2}{l} \left[y^2 - \frac{h_0^2}{4} \right] y = Cy \left[y^2 - \left(\frac{h_0}{2} \right)^2 \right],$$

with $$C = \frac{\rho_0 gk \, (\theta_1 - \theta_2)}{6\eta l}$$

*This classic reasoning has been used by Preston.[2]

The curve of speeds in the throat is represented in the Figure 27-b.

The maxima of the speeds occur at:

$$(10)\quad y = \pm\frac{h_0}{2\sqrt{3}} \text{ and are equal to:}$$

$$(11)\quad \mp C\frac{h_0^3}{12\sqrt{3}} = \mp 0.048\, C\, h_0^3$$

The tangent at the origin (0) is:

$$(12)\quad -C\frac{h_0^2}{4}$$

and the tangents against the walls:

$$(13)\quad C\frac{h_0^2}{2}$$

The maximum speed in the throat is proportional to the cube of the height of the throat.

c. *The flow through a throat. The quantity of heat transported.* Knowing the curve of speeds in the throat, it is easy to pass to the flow through that throat of some fluid drawing from one compartment towards the other. Per unit width of the throat, this flow is:

$$(14)\quad \int_0^{\frac{h_0}{2}} v\,dy;\ \text{is}\ \Phi_1 = \frac{Ch_0^4}{64}\ \text{or, in explanation:}$$

$$\Phi = \frac{\rho_0 gk}{384\eta l}(\Theta_1 - \Theta_2)h_0^4$$

For the entire width L of the throat, the flow is $\Phi = \Phi_1 L$.

The amount of heat transported from the hot compartment toward the cold compartment is as follows:

$$(15)\quad Q = \frac{c\rho_0 gkL}{384\eta l}(\Theta_1 - {}_2\Theta)^2 h_0^4$$

(c = specific heat of the liquid per unit volume)

It is proportional to the square of the difference of the temperatures and to the fourth power of the height of the throat (or of the height of the free bath under the barrier.)

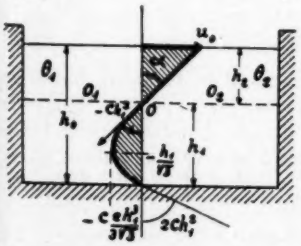


Fig. 28. Currents of a free tank, unobstructed.

d. *The unobstructed tank.* In the preceding discussion, the supposition has been that the liquid concerned was contained in two compartments which define the zones in which the temperatures Θ_1 and Θ_2 were prevalent. This separation is not necessary.

Let us consider a simple tank (Figure 28), and now, by whatever artifice, a difference of temperature $\Theta_1 - \Theta_2$ between two neighboring regions of the extremities. This brings us to a reconsideration of the canal viewed in the preceding paragraph, as constituting a tank in itself. The only difference is *that there is now no friction force on the higher free surface of the bath.*

Henceforth, we may consider in the tank a neutral line O_1O_2 situated at the level h_1, above which the curve of the pressures is positive and below which the curve is negative. In choosing this point for the origin, the equation of the pressures is:

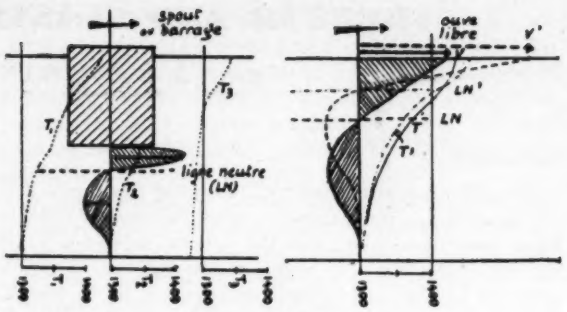


Fig. 29. Passage in a real tank.
Spout ou barrage = throat or barrier.
cuve libre = free tank.
ligne neutre = neutral line.

$$(16)\quad H = \rho_0 gk(\Theta_1 - \Theta_2)y,$$

y varying between $-h_1$ and h_2

$$(17)\quad (\text{with } h_1 + h_2 = h_0)$$

Between the bottom and the neutral line is found the same condition as previously described. Underneath the neutral line, the curve of speeds is the same as that which was determined above, and is:

$$(18)\quad v = C(y^2 - h_1^2)y$$

It is sufficient to replace $-h_0/_2$ by $-h_1$. The maximum of the return current occurs for the abscissa:

$$(19)\quad y = -\frac{h_1}{\sqrt{3}} \text{ and is equal (in absolute value) to:}$$

$$(20)\quad C\frac{2h_1^3}{3\sqrt{3}}$$

(21) The tangent at the origin O, is $\tan\alpha = -Ch_1^2$, and the tangent on the bottom is:

$$(22)\quad 2Ch_1^2$$

As there must be equality here of the incoming and outgoing flows, we shall determine the unknown h_1, in writing that the area under the curve situated beneath the neutral line is equal to the area beneath the right side. This side allows as its angular coefficient, the tangent at the origin of the preceding curve.

The first area is:

$$(23)\quad \frac{C}{4}h_1^4$$

$$(24)\quad \text{The second: } \frac{C}{2}(h_0 - h_1)^2 h_1^2$$

The equality (23) = (24) leads to:

$$(25)\quad h_1 = 0.586h_0$$

The neutral line, separating the direct current from the return current, is situated in the upper portion of the bath, at about 6/10 of the depth above the bottom.

The surface current is given by: $u_0 = -(h_0 - h_1)\tan\alpha$,

(26) which is: $0{,}142Ch_0^3$, or in explanation:

$$(27)\quad u_0 = 0.024\,\frac{}{}(\Theta_1 - \Theta_2)h_0^3$$

The speed of the superficial current is proportional to the difference of the temperature in the two compartments and to the cube of the depth of the bath.

The maximum of the return current, deduced from (20), is equal to:

(28) $v_m = 0.077Ch_0^3$, and is sensibly equal to half the surface current.

e. *Conveyance of heat in the unobstructed tank.* The

(*Continued on page* 166)

STRENGTH AND ELASTICITY OF GLASS FIBERS

By J. J. BIKERMAN and G. H. PASSMORE

Summary

The ultimate tensile strength, the total elongation and the modulus of elasticity of commercial glass filaments have been measured, and the results subjected to a statistical analysis. It is found that, whereas Young's modulus of a fiber is almost independent of its length, the ultimate tensile strength is the greater, the shorter the filament. The relation between the strength and the length of a specimen is quantitatively accounted for by the greater probability of a weak spot in a longer specimen. Since Young's modulus does not show dependence on the fiber diameter, it is very unlikely that fine filaments have a molecular texture different from that of glass in bulk. The high strength of fine filaments probably is due to the favorable orientation of the "flaws" in drawn specimens, the act of drawing being more important than the reduction in diameter.

Introduction

Thin filaments usually have a higher tensile strength than thick ones. That statement applies to metal wires, rayon threads, glass fibers, etc. All these filaments are thin because they have been stretched, and the two main theories advanced to account for the high strength of thin specimens assume the stretching (or drawing) to be the essential operation. One of these theories may be termed *molecular*. It attributes the high strength to a molecular orientation created by stretching or to another direct effect of drawing on molecules. In the science of glass J. B. Murgatroyd[10] is one of its most recent protagonists.

The *mechanical* theory, recently restated, for instance, by T. A. Kontorova[7] is more specific. It assumes that rupture starts at a "flaw" (an inclusion, an air bell, a crack, etc.) and a flaw is the more dangerous (that is, starts to grow at a smaller stress) the bigger is its cross-section normal to the fiber axis. On this view, the effect of stretching can be illustrated by the following simple example.

Consider drawing of glass fibers. Suppose that the glass blob from which a fiber is obtained, contains an air bubble having the volume $\frac{4}{3}\pi r^3$. If the bubble had retained its spherical shape in the fiber the radius of which is R, the ratio of the cross-sections bubble: fiber would have been $r^2 : R^2$. In reality, of course, the bubble is drawn out into a capillary the length of which may be denoted by l. That makes the cross-section of the capillary equal to $\frac{4}{3}\pi\frac{r^3}{l}$, and the ratio of the cross sections $\frac{4}{3}\frac{r^3}{R^2 l}$. Since l is so much greater than r, this ratio is much smaller than that, $\frac{r^2}{R^2}$, of the unstretched fiber. The "danger" of the flaw is reduced in the same degree, and the filament breaks at a higher stress. Doubtless the ratio of the cross-sections is only one of the factors determining the part played by a flaw, but a complete treatment of the matter cannot be attempted here.

Two kinds of experiments appear to afford the most direct test of the mechanical theory.

1. If thin filaments differ from thick ones only by the shape and orientation of their flaws, the modulus of elasticity (and other properties not associated with rupture) should be independent of the dimensions of the fibers. On the contrary, the elastic constants of a bundle of stretched molecules are likely to be different from those of random orientated or coiled molecules; hence the molecular theory expects Young's modulus to depend on the fiber dimensions.

2. If in agreement with the mechanical theory the variation of strength with length is due to the probability of a weak spot being greater in a long than in a short specimen, this variation should conform to the laws of probability. A simple probability test uses the statistical technique first applied to the strength of adhesive joints[2]. The breaking load of a specimen L cm. long is that of its weakest spot. If this specimen is cut into 10 pieces each L/10 cm. long, one of these pieces will contain the weakest spot of the original specimen while the remaining 9 pieces will have higher strengths. Therefore the lowest breaking load observed in a batch of 10 specimens of L/10 cm. should—on the average—be identical with the breaking load of specimens L cm. long. The molecular theories of tensile strength give no indication of a relation between strength and length.

In the preesent work both these tests were applied to commercial glass filaments and clearly confirmed the mechanical theory.

Experimental Procedure

The material. The major part of the work has been done on so-called continuous glass fibers*. 102 such fibers are simultaneously drawn at a high speed (near 20 meters per second) from a reservoir of molten glass, mechanically combined to a thread of parallel filaments, and wound on rotating drums. They are approximately 5×10^{-4} cm. thick and several kilometers long. The data summarized in Tables I and IV were obtained using single filaments, and those of Tables II and III using threads composed of 102 filaments.

For the bulk of the tests reported here fibers made of an alkali free glass of a low silica content were used; its exact composition cannot be stated. The data which served for a definite comparison, e.g., all the data listed in Table II, were obtained from one roll (one drum) of fibers; as a roll is completed within few minutes, the conditions of manufacture could not change much along one roll.

The measurement of tensile strength. Determination of ultimate tensile strength involves two measurements, that of breaking load and that of cross-section.

*The experiments were carried out in 1940.

The breaking load was found by placing small weights on a hook attached to the fiber, the upper end of which was attached to a solid support. The joints between fiber and hook and between fiber and support were made with bitumen. Bitumen with too low a melting point gave weak joints whereas very high melting bitumens were apt to damage the fiber, but medium sorts or mixtures of bitumens were found satisfactory. If the fiber broke at a joint, the result was discarded. The rate of loading for single fibers was about 0.1 gram per second and for composite threads about 5 gram per second. This is equivalent to an increase in tension of 5×10^5 gram/cm.sec.^{3} or 5 kg.-weight/sq.mm. per second for single fibers and 2.5×10^5 gram/cm.sec.^{3} or 2.5 kg.-weight/sq.mm. per second for threads. In Anderegg's experiments[1] the breaking load was independent of the rate of loading, and Rexer[12] found the tensile strength to be practically independent of the rate of increase of tension between 0.02 and 2 kg.-weight/sq.mm. per second.

The cross-section of single fibers was assumed to be circular and calculated from measurements of their diameters. In order to check this assumption bundles of fibers were pressed through a small hole in a brass slide and cut with a razor blade both above and beneath the slide. When examined under the microscope, many cross-sections could be seen at once. The majority of them were circular within the limit of the resolving power of the microscope (the magnification employed was 450 linear) but mostly some elliptical filaments were present as well. The diameter of a continuous fiber is only about 10 times the wave length of the yellow light; therefore, the microscopic test of the circular shape is not particularly sensitive.

An interferometer was employed to measure the fiber diameter. The fiber was placed between two optically polished glass plates. The lower plate was horizontal, and the upper plate rested with one end on the lower plate and with the other on the fiber, thus forming an air wedge. The plates were illuminated from above with sodium light. Dark and bright interference fringes were then visible parallel to the fiber. If the number of dark fringes between the fiber and the contact line of the two plates is n, and the wave length of sodium light is λ, the diameter of the fiber is $\frac{1}{2}n\lambda$. Readings were made to the nearest quarter of λ, i.e., the least difference between the diameters was taken to be 7.3×10^{-6} cm.

The cross-section S of the glass in a glass yarn (thread) can be determined by measuring the diameters of all the 102 constituent filaments and adding the areas of their cross-sections, but this technique would be too cumbersome. Therefore, the magnitude of S was found in the way usual in textile industry. If the length L of thread has mass M, then

$$S = \frac{M}{\rho L}, \qquad (1)$$

since the volume of the glass in the thread is SL; ρ is the density of the glass material. The alkali-free glass of the filaments had $\rho = 2.57$. The "count" is the number of meters weighing 1 gram. If this "count" is N, the cross-section is $\frac{1}{100\,N\rho}$ sq.cm. The "count" of the thread investigated was near 180.

The accidental error of the tensile strength data was unfavorably affected by humidity. The higher the humidity, the lower is the breaking load of glass fibers. It has unfortunately been impossible to keep the laboratory at a constant relative humidity. The variation of the breaking load due to variable humidity is therefore superimposed over that due to variation of the fibers themselves.

Systematic sources of error affected, perhaps, the determination of both breaking load and cross-sectional area. Since the weights were not added in infinitely small units, the breaking load observed might be higher than the real minimum load required for rupture. Consideration of this error would lower all the values for the tensile strength by 1-2 per cent. The determination of S from equation (1) seems to be quite safe, but the ellipticity of single filaments may somewhat falsify the value calculated for their cross-section. If a fiber having an elliptical cross-section is more likely to lie flat than to stand upright on the interferometer plate, the calculated cross-section will be smaller than the real one. On the other hand, as the distance between the interferometer plates is determined by the thickest spot of the fiber—as distinct from the average thickness—the values for the cross-section tend to be too high. In all probability both these effects are quite small.

The measurement of elasticity and total elongation. Determination of the modulus E of elasticity consists of four measurements according to the equation

$$E = \frac{W}{S} \frac{l}{\Delta l} \qquad (2)$$

W is the load applied, S the cross-section, l the initial length of the fiber, Δl the extension caused by W. For these measurements only single filaments were used.

The magnitude of S was calculated as stated above. The extension takes place chiefly at the thinnest part of the fiber where the ratio W/S has the highest value, but continuous fibers are so regular that the variation of S along the specimen was of no importance.

The extension Δl was found by means of a horizontal microscope which was focused on the lower end of the fiber suspended from a bitumen joint. To this bottom end a hook was attached which could be loaded with small weights. One division of the eye-piece micrometer scale corresponded to 0.0308 mm. of the object. Repeated observations at a constant load gave elongation values within 0.2 division so that Δl was known within ± 0.006 mm. The elongations ranged from about 0.1 to 3 mm. For short specimens the error of Δl was the most important in the determination of E but the uncertainty of S often was more important for long fibers.

In the vast majority of the observations the mark viewed with the microscope returned exactly to its initial position when the load was removed. There was therefore no indication of a plastic deformation of the glass, although the load applied sometimes exceeded 0.5 of the breaking load. In cases where the extension appeared irreversible, it could be traced to slippage of the filament in the bitumen joint or to another effect of a similar nature. These cases were disregarded.

For the measurement of the total elongation the hook hanging on the fiber was rigidly connected with a fine horizontal wire which could slide over the surface of a blackened sleeve of paper wrapped round a brass cylinder (from a recording instrument). When the hook was

loaded, the wire made a vertical mark on the soot, and the length of the mark traced when the fiber was broken in tension was the value Δl. The precision of the method was only 3-5 per cent, but it was sufficient to show that Hooke's law was valid up to the breaking load.

The values of l and Δl are each subject to a systematic error; both of these errors tend to reduce the value of E. The length l substituted into equation (2) is, of course, that between the points of contact "fiber-upper joint" and "fiber-lower joint." If, however, the fiber has some freedom of movement within the bitumen, an extension takes place there as well and the effective length is greater than l. The value of Δl represents the real extension of the fiber if the latter is perfectly straight and vertical along the whole of its length. If, as often happens when sufficient care is not exercised, the fiber leaves the bitumen joint under a considerable angle to the vertical, then the load applied straightens the fiber as well as extends it, and the observed value of Δl is too large.* Too small values of l and too great values of Δl cause E to appear erroneously small.

Besides affecting the absolute value of E these errors cause an apparent increase of it when the length of the specimen or the applied load is raised. It is easily understood that the errors localized in or near the joints are reduced in importance when the distance between the joints or the elongation increases. In our work particular attention has been paid to eliminating the sources of these errors.

Experimental Results

Ultimate tensile strength. Table I summarizes the results found on over 600 single filaments. They are formed into three groups according to the average length of the specimens. The average diameter of these filaments was 5.35×10^{-4} cm.

TABLE I.

Ultimate Tensile Strength of Short, Medium and Long Glass Filaments.

	Short	Medium	Long
Number of observations	210	258	138
Average length in cm.	4.5	18.6	87
Average tensile strength in kilobars	26.3	22.9	16.8
in kg.-weight/sq.mm.	268	233	171
in 10^3lb./sq.in.	381	331	243
Standard deviation in kilobars	4.8	3.8	4.8
Standard error of the mean in kilobars	0.33	0.24	0.41

Tables II and III refer to composite threads, i.e., to bundles of 102 single continuous filaments. Table II shows the highest, average and lowest breaking load (in gram-weights) for 5 cm. long threads arranged in 26 batches of 10 observations each. The last column lists the 26 individual results obtained on threads 50 cm. long. The ten short specimens of a batch and the corresponding long specimen were all taken from one long piece of thread.

Table III lists the lowest breaking loads in batches of 8 specimens 1.7 cm. long and the individual values of the breaking load of 13.6 cm. long specimens (13.6 is 1.7×8). Again, each thread consisted of 102 parallel filaments, and all the specimens used for preparation of Table III originated from one roll.

*A. K. Burov et al. (4) determined Young's modulus of glass fibers by measuring the extension of a stretch between two marks on the filament.

TABLE II.

Breaking Load of Long and Short Glass Threads.

Batch Number	Highest	Mean	Lowest	Individual
	Breaking Load in Gram Weights			
	for 5 cm.			for 50 cm.
(1)	450	415	360	365
(2)	445	408	355	250
(3)	440	409	385	310
(4)	460	405	350	330
(5)	470	424	370	325
(6)	440	396	350	320
(7)	415	376	345	300
(8)	460	404	350	355
(9)	465	433	375	355
(10)	465	425	365	370
(11)	485	455	380	415
(12)	485	457	390	405
(13)	495	446	370	350
(14)	485	436	370	360
(15)	470	430	380	290
(16)	460	421	380	405
(17)	475	444	400	415
(18)	450	407	360	400
(19)	475	418	375	355
(20)	480	426	380	370
(21)	440	413	380	445
(22)	480	421	365	375
(23)	475	441	390	395
(24)	475	416	345	395
(25)	470	441	390	375
(26)	470	414	350	385
Mean	465	422	370	362

Modulus of elasticity and total elongation. In Table IV the values of Young's modulus are compared for 25 long and 25 short specimens; all the specimens were single filaments.

TABLE III.

Breaking Load of Long and Short Glass Threads.

Batch Number	Lowest	Individual
	Breaking Load in Gram Weights	
	for 1.7 cm.	for 13.6 cm.
(1)	394	427
(2)	384	410
(3)	384	375
(4)	384	404
(5)	404	376
(6)	384	334
(7)	384	364
(8)	394	427
(9)	384	361
Mean	388	386

If Hooke's law is valid up to the point of rupture of the filament, the modulus of elasticity can be calculated

(*Continued on page* 168)

TABLE IV.

Young's Modulus of Long and Short Glass Filaments.

	Short	Long
Number of observations	25	25
Average diameter in 10^{-4} cm.	5.7	5.6
Average length in cm.	2.9	14.2
Range of lengths in cm.	1.2-4.5	12.4-20.8
Average modulus of elasticity E		
in kilobars	733	812
in kg.-weight/sq.mm.	7,470	8,280
in 10^3 lb./sq.in.	10,630	11,780
Standard deviation of E		
in kilobars	129	133
Standard error of the mean		
in kilobars	26	27

WORKERS IN WINDOWLESS FACTORIES ARE SUBJECT TO CLAUSTROPHOBIA

By ERNEST A. DENCH

Natural light streaming through the windows of an industrial plant on a winter's morning is worth a dozen production pep talks.

Workers are people—and people are human. It seems only yesterday that they emerged from dark caves. Every child has a fear of darkened places—a fear inherited from pre-historic man. When that modern child becomes a man or woman, he or she loses her fear of the supernatural; but the condition manifests itself in another form — claustrophobia — "morbid dread of confined places" (Funk and Wagnall Standard Dictionary definition).

It occurs when working in a building without windows to look through or open. Even though there are doors handy, the worker feels he is imprisoned within. Artificial light, even if the visibility equivalent of perfect daylight, is no cure for claustrophobia.

The writer is conceited enough to believe he is an intelligent person, and the possessor of an analytical mind. If he were not, he would be mentally incapable of writing this article.

He recently attended an industrial convention in a Pennsylvania city. The official hotel was filled from the basement to the top floor with delegates. The writer and some forty-nine other guests were assigned to the basement area, converted during wartime into bedrooms. The writer is stretching a point by describing them as bedrooms. In actuality, two rows of cubicles flank a corridor. Each room is about the size of a hall bedroom in a city rooming house, and contains a single bed, chair and a small table. Neat and clean as the proverbial pin. A fluorescent lighting unit over the bed; and directly back of it, an air-conditioning unit in action. Composition board partition, which does not quite reach to the ceiling, provides the physical privacy between adjacent cubicles. As to vocal privacy, there is none.

No cubicle has a window. What the writer missed most (and fellow cubicle occupants confirmed the writer's reaction) was the noticeable change from the blackness of night to the gradual morning light, and also the opportunity to check up on weather conditions—rain, snow, sleet or clear—outside. The writer had to depend on sound to check up on approximate times without watch consultations. He knew when it must be around midnight, for then the clanking of the old-fashioned trolleys ceased. The advent of six A.M. was indicated by a re-occurrence of this metallized racket.

Another intelligent and highly-educated type of man is the architect. A member of this profession recently traveled from sunny South Africa to equally sunny South California. He expected that climatic similarities in winter would yield appropriate ideas. He might as well have gone to Alaska, where winter daylight is confined to a few hours. As he stated: "It is depressing to walk out of the bright sunlight into an artificially lit room, however cleverly concealed the handiwork of man may be. To my mind, the only excuse for artifical lighting lies where cramped space makes it essential. Where possible to introduce natural light, use it."

If women do not like gloomy homes, it stands to reason they react the same unfavorable way to similar working conditions in factories, stores and offices. Woman is an emotional creature, and will work best when the environment approaches her ideal.

The factual evidence hinges on a block of almost fifty thousand *McCall Magazine* readers. Back in 1945 they frankly told what they did not like about their homes. Insufficient daylight entering specific rooms aroused such typical comments as—

Kitchen: "It is dark and gloomy."
Dining Room: "It is gloomy."
Living Room: "There are not enough windows."
Bedroom: "It has only one window."

"Lighting from windows is, for the most part disregarded," is a true statement to be found in the plant manual of the Graphic Arts Association of Illinois.

Before building a new plant, or remodeling the present one, the industrialist should in fairness to his workers, ask them the simple question on a printed or mimeographed slip: "*Do you prefer the new plant to have windows?*" If yes, give your reason: ..... If no, give your reason: .....

There should be, somewhere on the printed or mimeographed slip, a brief explanation that the management is undecided whether the new or remodeled plant is to be windowless. Efficiency advantages of same should be stated.

Were choice put to the workers' vote in the way indicated, the writer is confident that an overwhelming majority would be in favor of what might be termed a "look-see" plant.

Such an act will, during the next few years, be a *foresighted* one in employee-employer relations. The human element in this phase of plant construction has been ignored to date.

The way the unions ferret out grievances of their members, or use a long-repressed desire of one member as a test case, leaves many an employer breathless—and helpless. Some of the states, through their labor and industrial health departments, are not very far behind the unions in pressing for reforms in working conditions.

The employees themselves, even if not unionized or backed up by a new state law, may, when least expected, rebel at being deprived of natural daylight in the new or remodeled windowless plant.

Artificial lighting in daylight hours will not be the issue. Most employees will be in favor of a coordination of natural and artificial lighting, for the good and simple reason that natural light is not sufficient on dull days, or during certain hours of bright days, for efficient working conditions. This applies, too, to those factory areas located at a considerable distance from the windows.

The real issue is the *windowless* plant. Few, if any,

(*Continued on page* 170)

G.C.M.I. ANNOUNCES 1948 SPRING MEETING

The Glass Container Manufacturers Institute has announced that its 1948 Spring Meeting will be held at White Sulphur Springs, West Virginia, on May 3, 4 and 5.

The scheduled program for the three days is as follows: May 3 and 4 will consist of meetings under the auspices of the Board of Trustees for the purpose of receiving semi-annual reports from the nine standing committees and making the same available to the industry generally. On May 5, the annual membership meeting will be held. This meeting is open only to glass container and closure manufacturers and allied and supplier companies that are regular members of the Institute. The election of four Trustees to serve a three-year term will also be held on this date.

APPOINTMENTS AT BALL BROTHERS

The appointment of V. J. Cox as Industrial Relations Director for its nine plants has been announced by Ball Brothers Company. Also announced was the appointment of Horace Weber as Personnel Manager.

Mr. Cox was formerly associated with the Indiana State Chamber of Commerce as an industrial relations advisor and was in charge of industrial and public relations for the Muncie Gear Works for a year before he joined the staff of the General Superintendent of the Ball glass division in 1945. Mr. Cox had previously been associated with Ball Brothers as Personnel Manager for the Muncie plant in 1937. He served in that capacity until the early part of 1944 when he accepted the position with the Muncie Gear Works.

Mr. Weber joined Ball Brothers in 1944 and was engaged by the Engineering Department specifically to design and supervise the construction of a sewage disposal plant at the company's Hillsboro factory. Upon completion of this construction, Mr. Weber was transferred to the Industrial Relations Department.

KIMBLE GLASS APPOINTMENTS

Walter W. Wood has been named Personnel Director and Allan D. Campbell, Director of Purchasing, for the Kimble Glass Division of Owens-Illinois Glass Company, it has recently been announced.

According to the announcement, Mr. Wood will be responsible for personnel procurement and job instruction within the Kimble Division, as well as the food service provided employees and maintenance of efficient labor relations.

As Director of Purchasing for the Kimble Division, Mr. Kimble will supervise all purchasing procedures and direct the activities of personnel assigned to the purchasing function within the Division's various plants and departments. He will also be in charge of stores and material inventories and direct the preparation of purchasing reports and records.

• Professor Alexander Silverman, Head of the Department of Chemistry, University of Pittsburgh, will address the Western New York Section of the American Chemical Society in Buffalo, New York, on March 16. His subject will be "The Last Decade in American Glass Manufacture."

HARTFORD-EMPIRE SETTLES SEVEN SUITS

Seven of nine suits, mostly for triple-damages which were based on the Toledo Anti-Trust decision, have recently been settled out of court by the defendant, Hartford-Empire Company. The total cost of settlement of these seven suits amounts to approximately $2,800,000. The plaintiffs with whom settlements have been made are Glenshaw Glass Company, McKee Glass Company, Obear-Nester Glass Company, Three Rivers Glass Company and Peter Kucera.

Two other suits against Hartford are still in the process of litigation. In one, the Turner suit, there are four other companies involved, these other four being glass container manufacturers. This action was started in 1942. Up to this time a Master report has been issued which has recommended dismissal of the suit. However, the Court has not yet passed upon this report.

The pending suit is one brought by the Department of Justice in Delaware. In this case, which has not yet come to trial, the Government seeks cancellation of four patents.

BOOK REVIEW

A Russian Book on Coating Optical Glass

I. V. Grebenshchikov, A. G. Vlasov, B. S. Neporent and N. V. Suikovskaya published in 1946 a book on "Clarification of the Optics. Reduction of the Reflection of Light from the Surface of Glass."

This book is a result of 15 years of research work in the State Optical Institute in Leningrad. It reviews all methods suggested and employed for reduction or elimination of light reflection from the surface of optical glass. The method now in use consists in depositing on the glass surface a film (about 1375 angstroms thick) of a suitable low refractive index. The authors worked out a new device using double coatings; the glass is coated with a film having a high refractive index, and a film having a low refractive index is produced on top of the first one. Also the problem of increasing the light reflection is dealt with. This increase is achieved by coating glass with titanium dioxide.

The book is 212 pages long, its price is 9 rubels, and the publishing house is Gostekhizdat, Moscow and Leningrad.

COMMERCE DEPARTMENT REPORT ON MIRROR COATING

A process for coating telescope and periscope mirror surfaces with an oxide of silicon is described in a report now on sale by the Office of Technical Services, Department of Commerce. Aluminum mirrors coated in this manner are said to have a reflectivity of 90 per cent. The report was prepared by OTS investigators, Drs. J. E. Tausz and M. Tausz.

Briefly, the process is carried out in high vacuum, using a heating element to volatilize the oxide, the report states. The oxide deposits on the mirror surface to form a hard coating for protection against abrasion. The oxide of silicon is of doubtful composition, but it is a lower valence compound than the dioxide. It is prepared by sublimating a mixture of silicon and silicon dioxide and is believed to be a mixture of silicon, silicon monoxide and silicon dioxide. The mirrors were sold at 6 to 10 marks per square decimeter of coating.

Mimeographed copies of the 11-page report (PB-79599, "The protective coating of mirror surfaces with an oxide of silicon," sell for 50 cents.

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Glass Compositions

Corning Optical Glass. Fig. 1. Patent No. 2,435,995. This patent is the invention of William H. Armistead, who assigned it to Corning Glass Works. The patent relates particularly to a glass having an index of refraction for the D line (nD) greater than 1.60. Former glasses of this type were usually a dense flint or lead glass having a high lead content. Such glass had a low dispersive index (nu value) which was not satisfactory for certain purposes. This inventor has found that certain silicate glasses with a high cadmium content have the desired optical properties, improved chemical durability and increased resistance to devitrification.

The diagram shown in Fig. 1 plots the relationship between nD and ν for the 19 examples of glasses within the scope of this invention, these batches being calculated in per cent by weight. The examples given in the patent are as follows:

	A	B	C	D	E	F	G	H
SiO_2	35	30	30	30	15	20	23	10
CdO	40	40	50	50	35	25	60	30
Al_2O_3 ...	20	25	15	20	10	5	10	5
B_2O_3	5	5	5	...	15	10	5	10
BaO	...	...	...	...	25	40	...	45
Li_2O	...	...	...	...	...	...	2	...
*n*D 1.6195	1.6268	1.6503	1.6525	1.6697	1.6777	1.7125	1.7179
ν	48	48	45	45	47	50	41	43

	I	J	K	L	M	N	P	R
SiO_2	30	20	10	10	15	10	20	15
CdO	65	65	30	70	70	75	75	70
Al_2O_3 ...	...	5	...	10	5	5	...	...
B_2O_3	...	10	10	10	10	10	5	10
BaO	...	...	45	...	...	...	...	...
ZrO_2	...	...	5	...	...	...	...	5
Na_2O ...	2	...	...	...	...	...	...	...
K_2O	3	...	...	...	...	...	...	...
*n*D 1.7216	1.7269	1.7417	1.7614	1.7645	1.7863	1.7917	1.7998
ν	37	40	42	36	37	33	35	36

	S	T	U
SiO_2	5	7.5	18
CdO	75	60	40
Al_2O_3 ...	10	5	...
B_2O_3	10	7.5	2
PbO	...	20	40
*n*D 1.8067	1.8604	1.8883
ν	32	26	25

The lines X and Y in the diagram represent the approximate minima in the values for nD and ν in glass according to this invention.

The only patent of record in the file of this patent is No. 2,298,746, dated Oct. 13, 1942, to Moulton.

Miscellaneous Processes

General Electric Sealing-in Machine. Fig. 2. Patent No. 2,434,664. This machine was the invention of Frank J. Malloy, deceased, of University Heights, Ohio, and his executrix assigned it to General Electric Company. The invention is particularly useful for fusing the flared stem tube of a mount for a fluorescent lamp into the open end of the tube. The invention can be used to seal together commercial stems and bulbs which may vary slightly in shape.

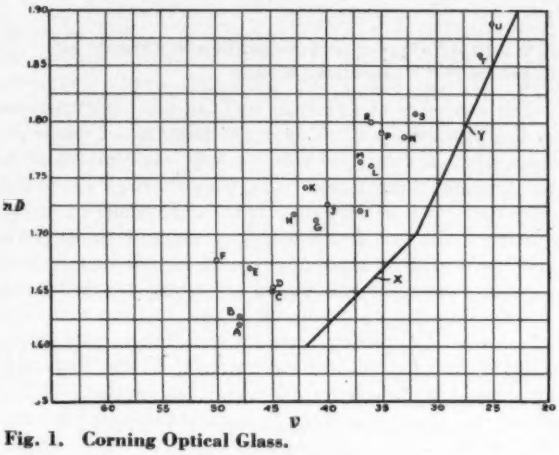


Fig. 1. Corning Optical Glass.

Fig. 2 shows a plan of the machine and a vertical section through one of the 16 heads. These heads are carried on the periphery of a turret 12 and the heads support the mounts 13 and bulbs 14. As the turret turns, the heads are advanced to work stations A to Q. The mount shown in the drawing is the same as that dis-

(*Continued on page* 166)

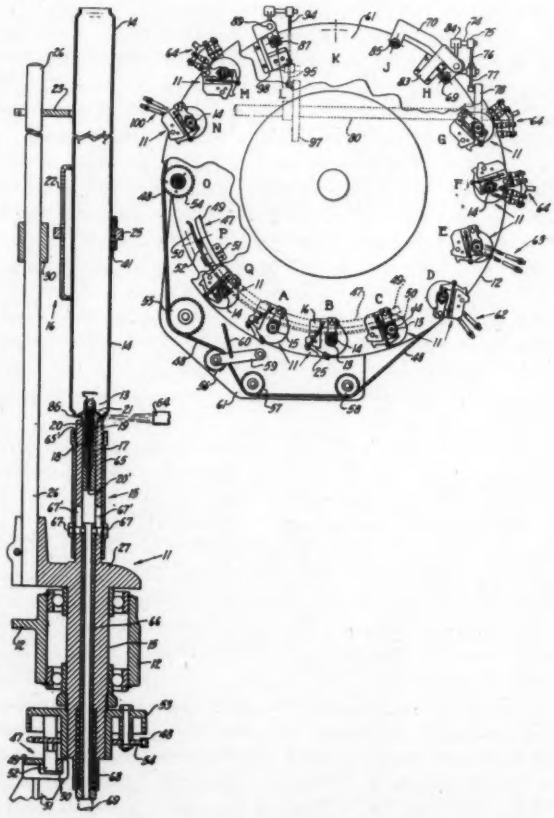


Fig. 2. General Electric Sealing-in Machine.

Research Digest

A Study of Time and Temperature Effects on Glass in the Annealing Range

The annealing and "compacting" of glass is important to the precision optical industry because of the three characteristics associated with the heat-treatment, namely, (1) freedom from stresses; (2) homogeneity of physical properties, such as refractive index and coefficient of expansion (chemical homogeneity is assumed to prevail, since lack of it, evidenced as striae, cannot be tolerated nor can it be alleviated by the annealing process); and (3) stability of these properties.

The term "annealing" has by tradition become associated with the release of stresses only so that there are advantages in the use of the term "compacting" to describe the process leading to achievement of (2) and (3) of the above requirements. Both of these terms, however, refer to processes taking place concurrently during the cooling process through and even below the "annealing region." For simplicity, the term "annealing" was used alone in the rest of this paper.

Although accomplishment of the first objective, freedom from stresses, is sufficient for such lenses as condensers and magnifiers, it is necessary to achieve physical homogeneity as well for such image-forming systems as telescope and projection objectives. The polariscope is adequate for determining the presence or absence of birefringence due to stresses, whereas only the interferometer can give a reliable indication of the degree of physical homogeneity attained. In other words, the polariscope indicates the degree of annealing, while the interferometer indicates the degree of "compactness."

Fine annealing schedules are therefore required because, first, the slower cooling rates involved produce smaller temperature gradients throughout the work which in turn lead to greater freedom from stresses and greater physical homogeneity, and, second, the finer schedules yield a more stable condition of the glass. Since the time necessary to accomplish these various degrees of approach to the most stable state increases rapidly as the closer approach is made, the development of the most efficient schedules becomes more important economically in these cases.

The search for more efficient fine-annealing schedules led the author (P. W. Collyer, *Journal of the American Ceramic Society*, November, 1947) to obtain curves of refractive index versus time. The work was done on samples of borosilicate glass which had been rapidly quenched from a temperature of 1075°F. by holding them for periods up to 500 hours at constant temperature. The refractive index for sodium light was measured for each sample (triple checked) by a Pulfrich Refractometer.

The equilibrium condition was attained to a very close approximation at several temperatures and this nearness of approach made possible the comparison of various proposed equations (Winter, Maxwell, McMaster and Tool) relating the change of properties to their equilibrium values.

After it was shown that equations expressing $\frac{dn}{dt}$ as first or second degree functions of (ne—n) did not seem to fit the present data, the equation proposed by Tool was transformed to give the following expression for the rate of change of index:

$$\frac{dn}{dt} = Q(ne-n)e^{\frac{n}{P}}$$

where

$$Q = M\,Ko\;e^{\frac{T}{g}}$$

t = time
n = refractive index
ne = equilibrium value of n
T = temperature
P, M, Ko, g = constants

It was shown that this equation appears to represent adequately the changes of index derived from the data obtained in this study and also those of previous investigators.

As a result of this study, an annealing schedule accomplishing an approach to the most stable condition was worked out which decreased the time from 12 days to about 7 days.

Observations on the Shelling of Checker-Brick

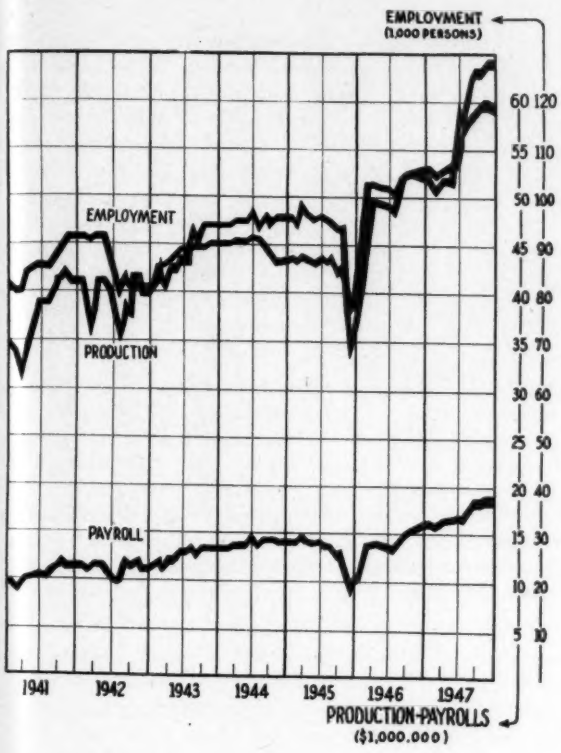
During the past several years, various investigators have studied the phenomenon connected with the failure of checker-brick resulting from alkali pickup or absorption in glass-tank regenerators. The carry-over from the tank comes in contact with the refractories in the regenerator chambers and may cause erosion, impregnate the brick, or clog the flues, depending on the temperature at various levels in the setting. If the temperature of the top courses exceeds 2700°F., moderate to severe erosion can be expected with the resulting washing of the refractories. In the intermediate temperature zone, below 2700°F., erosion generally does not occur but the carryover dust deposits on the checkers and may react with the surface of the brick to form either nephelite (or carnegieite), $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$. In the lower sections of the setting, where the temperature does not exceed 2100°F., build up of the carryover generally occurs with no erosion or apparent alteration of the brick surfaces. The evidence in this paper (Petrie and Brown, *Journal of the American Ceramic Society*, January, 1948) shows that alkali pickup occurs in the lowest temperature zone. When such brick are cleaned and returned to checker service at higher temperatures, prompt failure occurs in the form of erosion or shelling.

The shelling of checker-brick may be best described as the process of removing successive layers of the refractory by a combination of chemical and thermal actions until the efficiency of the unit is greatly impaired or

(*Continued on page* 152)

CURRENT STATISTICAL POSITION OF GLASS

GI THE GLASS INDUSTRY'S INDEX



December 1947 figures covering activity in the glass industry as shown in the Production Index remained about the same as for the previous month. Activity during November and December was an estimated $64,750,000. During December 1946, glass production was about $57,000,000, which is about 13 per cent below December 1947. Total glass output for the entire year of 1947 has reached an estimated total of $721,000,000. During the corresponding twelve months of 1946, the figure reported was $605,500,000, which is about 19 per cent below 1947.

Employment and payrolls: Employment in the glass industry during the month of December 1947 dropped only slightly from the 120,000 reported for November. The December figure is 119,700. Employment during the month of December 1946 was 104,000 persons. This is about 15 per cent less than for December 1947.

Payrolls for the month of December 1947 remained about the same. Thus, the estimated figure for both November and December is $18,500,000. During December 1946, payrolls were approximately $16,000,000. This is about 15 per cent below December 1947. During the entire year of 1947, glass manufacturers have paid out approximately $203,500,000. This is about 26 per cent above payrolls for the corresponding period in 1946, which were $160,500,000.

Glass container production, based on figures released by the Bureau of Census, rose not quite 1 per cent during January 1948 from the 7,998,024 gross produced during December 1947. The January figure is 8,055,842 gross. Production during January 1947 was 11,154,977 gross, which is the all-time high for glass containers. This represents a difference of about 27 per cent.

Shipments of glass containers for the first month of 1948 fell off slightly to 7,417,507 gross from the 7,991,488 gross shipped during December 1947. Total shipments during January 1947 were 10,405,271 gross. This is about 28 per cent above January this year.

Stocks on hand at the close of January 1948 are 8,414,716 gross. At the close of December 1947 stocks were 8,056,859, and 4,167,273 gross at the close of January 1947.

(*Continued on next page*)

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in gross)

		Production January 1948	*Stocks January 1948*
Foods; Medicinal & Health Supplies; Chemicals, Household, Industrials; Toiletries and Cosmetics	Narrow Neck	2,355,493	2,895,311
	Wide Mouth	2,149,898	2,110,070
Dairy Products		339,215	260,747
Home Canning		122,484	712,642
Beverages, Returnable		621,834	828,069
Beverages, Non-returnable		.....	.....
Beer, Returnable		1,173,760	686,609
Beer, Non-returnable		248,052	270,686
Liquors		678,924	356,217
Wines		274,401	215,443
Packers' Tumblers		91,781	78,922
Total		8,055,842	8,414,716

GLASS CONTAINER SHIPMENTS

(All figures in gross)

Narrow Neck Containers	*January 1948*
Foods	532,206
Medicinal & Health Supplies	1,013,909
Chemical, Household & Industrials	418,108
Beverages, Returnable	412,499
Beverages, Non-returnable	.....
Beer, Returnable	581,162
Beer, Non-returnable	227,631
Liquors	612,240
Wines	243,217
Toiletries & Cosmetics	392,845
Sub-Total (Narrow)	4,433,817
Wide Mouth Containers	
Foods	1,733,828
Dairy Products	247,209
Home Canning	*27,089
Medicinal & Health Supplies	259,008
Chemical, Household, Industrials	70,172
Toiletries & Cosmetics	126,694
Packers' Tumblers	92,809
Sub-Total (Wide)	2,556,809
Total Domestic	6,990,626
Export Shipments	426,881
Total Shipments	7,417,507

*This figure includes Fruit Jars only.

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Plate glass production for the month of January 1948, according to the Hughes Statistical Bureau, continued to rise and was reported to be 21,957,561 sq. ft. This is about 9 per cent above the 20,088,647 sq. ft. produced during December 1947. Plate glass production during January 1947 was 21,979,614 sq. ft., which is only slightly more than for January this year.

Automatic tumbler production for the month of January 1948 was 4,733,982 dozens. This represents a decrease of about 4½ per cent from the 4,944,176 dozens produced during December 1947. Production during January 1947 was 7,585,781 dozens. Shipments for January were only slightly lower than for the previous month: January 1948, 4,566,993 dozens and December 1947, 4,598,957 dozens. Shipments during January 1947 were 6,352,415 dozens. Stocks on hand at the close of January 1948 were 8,733,697 dozens; at the close of December 1947, 8,923,753 dozens; and at the close of January 1947, 5,095,222 dozens.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware for the month of January 1948 dropped about 2 per cent to a figure of 3,233,516 dozens from the 3,421,535 dozens sold during December 1947. Sales during January 1947 were 4,489,302 dozens. Total manufacturers' sales during the 12-month period ending January 1948 were 41,100,088 dozens, as compared with 46,970,821 dozens.

Because of lateness, one company's figures are not included in the figures for automatic tumbler production and table, kitchen and household glassware. However, the totals for this company have been estimated for the compilation of the above figures and if you follow this department regularly, you will note that the figures are adjusted in the following issue when such an instance as this arises.

RESEARCH DIGEST . . .
(*Continued from page* 150)

destroyed entirely in certain temperature zones.

In this work, brick which had been installed in glass tank checkers, removed, cleaned and returned to service at higher operating temperatures, were examined and were found to exhibit excessive bloating and shelling. Chemical analyses of the several samples indicated that this was due to pick-up of excessive alkalies.

AMERICAN POTASH STOCK REPORT

American Potash & Chemical Corporation has announced a dividend of 37½c per share on Class A stock and Class B stock, payable on March 15, 1948, to holders of record on March 1, 1948.

The Board of Directors also declared a quarterly dividend of $1.00 per share on the corporation's $4.00 cumulative preferred stock, Series A, also payable March 15 to holders of record March 1.

Photo courtesy Becton, Dickinson Co.

HF *hydrofluoric acid*

Glass factories everywhere use Pennsalt hydrofluoric acid . . . and have found that it fulfills exacting requirements . . . from etching precision glass medical instruments to frosting, polishing and etching fine decorative glassware.

Pennsalt HF acid is furnished in strengths of 30%, 52%, 60%, 70% and 80% for domestic users. Strengths above 60% shipped in steel containers. Lower strengths in rubber drums. Write for full details. Heavy Chemicals Division, Pennsylvania Salt Manufacturing Company, Philadelphia 7, Pa.

Photo courtesy Cambridge Glass Co.

Photo courtesy Cambridge Glass Co.

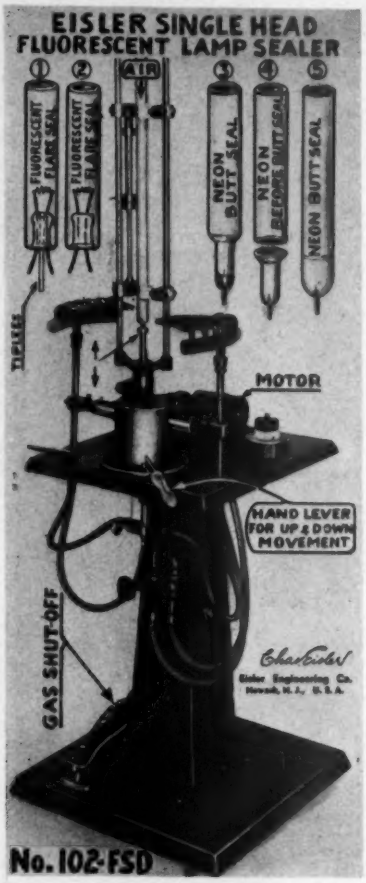
OTHER
PENN SALT
PRODUCTS
for the glass industry

Ammonium Bifluoride
Aluminum Hydrate Ferric Chloride
Kryolith (Natural Greenland Cryolite)
Muriatic, Nitric, Sulfuric Acids
Salt Cake

NEW EQUIPMENT AND SUPPLIES

EISLER FLUORESCENT LAMP SEALER

Eisler Engineering Company, Inc., Newark 3, New Jersey, is manufacturing an improved single-head fluorescent lamp sealing machine designed especially for laboratory or working shops



with moderate production of this sign and lighting unit.

The essential components of the machine mounted on a fabricated sturdy stand comprise a special sealing head-holder for long tubing with driving mechanism, adjustable cross-fires with a gas-air mixer, an economizer, necessary rubber hose connections and a fractional H.P. electric motor with a three step cone-pulley drive.

The driving mechanism, encased in a cylindrical cast housing, consists of a worm gear, driving the head in combination with a friction clutch, the purpose of which is to stop the head rotating without stopping the motor run in order to facilitate loading and unloading the tube holder. Also, a push up and down arrangement is operated by a hand lever for raising and lowering the sealing rod. Stopping the head from rotation, as mentioned above, is initiated by turning a knurled head pin to match with a pin hole on the gear housing. To resume rotation of the head again, the pin is simply pulled out and turned back.

The single head sealer shown in the illustration seals in fluorescent lamps up to 2″ in diameter but can easily be adapted to other sizes. The average production of the machine is about 50 to 75 seals per hour, mainly depending on the versatility of the operator. For larger volume production, fluorescent tube sealing machines are made in 8 and 10 head models.

GLASS TUBING CUTTER

Eberbach & Son Company, Ann Arbor, Michigan, has announced the even heat glass tubing cutter with which glass tubing up to 7½″ outside diameter can be cut in any position, as a separate piece or as an integral part of apparatus already set up.

Adjustable supports are provided for the hot wire cutting unit and for the tubing when individual pieces are to be cut, but the hot wire cutting unit can be used in any position when detached from its support. A foot switch is available as an accessory for controlling the power when the operator wants to have both hands free for the cutting operation.

Power for the variable length cutting wire is supplied by a special power unit, and a meter on this unit enables the operator to balance the electrical output with the variable wire length.

Another feature of the even heat glass tubing cutter is elimination of electrical shock hazard. The hot cutting wire carries low voltage which is isolated and insulated from the power line.

NEW LABORATORY KIT

Fischer & Porter Company, Dept. 9M-J, Hatboro, Pa., has announced a new Laboratory Kit (rotameter type) designed to fill the need for a versatile and inexpensive flow measurement "set" to meet the varied flow measurement requirement of the research laboratory.

The kit consists of a metering tube holder with base plate and hose connectors, four readily interchangeable tubes and six metering floats complete with calibration data. Capacities from 0.065 to 2200 cc/mm of water and 5.0 to 36,800 cc/min. of air are covered.

CATALOGUES RECEIVED

Reinhold Publishing Corporation, 330 West 42nd Street, New York 18, N. Y., has just issued the 1947-48 edition of the Chemical Engineering Catalog.

The book provides a collected source of condensed and standardized data about equipment, machinery, raw materials, heavy and fine chemicals and laboratory supplies used in the industries employing chemical processes of manufacture with classified indices of such equipment and materials carefully cross-referenced.

The book also contains a Technical and Scientific Books Section, cataloging and describing briefly a selected list of books on chemical and related subjects.

Westinghouse Electric Corporation, Advertising and Sales Promotion Department, Lamp Division, Bloomfield, New Jersey, has issued a new 24-page booklet, A-5112, describing sixteen types of mercury vapor lamps.

The booklet contains detailed information on electric discharge through vaporized mercury, technical data for the 16 types of vapor lamps available, spectral radiation characteristics of vapor lamps at different arc pressures, auxiliary equipment available, operating characteristics of vapor lamps, lamp construction, lamp life and lumen maintenance, effect of ambient and lamp temperatures on lamp life and application information.

American Instrument Co., Inc., Silver Spring, Maryland, has published a new, 28-page bulletin giving a comprehensive description of a complete line of electric hygrometer equipment suitable for the more exacting industrial and laboratory applications.

The booklet is illustrated and lists, among other devices, a tiny sensing element that responds within a fraction of a second to increases or decreases of relative humidity as small as 0.1 per cent. The booklet explains how this element measures with an accuracy of within plus-minus 1½ per cent relative humidity when used with suitable equipment.

Dings Magnetic Separator Co., Milwaukee, Wisconsin, has issued Bulletin No. 1120 which describes the operation of its laboratory in solving separation problems in many industries.

The purpose of the laboratory, whose service is free, is to analyze materials, to determine if, and how best, they can be magnetically separated and to develop new and improved separators. The procedure to be followed in arranging for product tests is described.

Aget - Detroit Company, Ann Arbor, Michigan, has released a new four-page bulletin, No. 510, entitled "Put a Permanent Stop to Dusts."

Dust collectors for stopping dusts and lint from grinding, polishing and buffing operations are illustrated. Various installations are shown with descriptive matter and price included with each.

Vapor collectors to trap the mist and vapor from thread grinders and centerless grinders are also included in the bulletin, together with prices of the units.

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(*Continued from page* 136)

for example, assumed that B_2O_3 and SiO_2 showed the phenomenon of immiscibility. Later work brought out, however, that these two oxides are miscible in all ratios, but that their diffusion speed in the melt is so low that it requires a long time and high temperatures to homogenize the melts. (Cousen and Turner, 1928)

Devitrification of vitreous borates were studied by J. F. Ponomareff, who developed his method of "enforced crystallization" in order to obtain crystals from those glasses which do not readily devitrify. The phenomenon of immiscibility of borates was extensively studied by M. Foëx, who produced quantitative data concerning the mutual solubilities of many oxides with B_2O_3.

Alkali borates as solvents for silicates and phosphates were studied by H. S. van Klooster with the aim to find out whether or not the acidic constituents would form a complex acid in the fused salts.

For the development of fluorine opal glasses and for special light absorbing and transmitting glasses, it is of interest to learn something about the solubility of alkali halides in glass. B. Stalhane determined the mutual solubilities of fused alkali borates and alkali halides. He found that the mutual solubility decreases with increasing B_2O_3 content, but increases only slightly with increasing temperature. No critical temperature was found above which the two salts gave homogeneous melts in all ratios. Only the fluorides showed complete miscibility, and it is noteworthy that the presence of fluorides in a borate melt increased its solvent power towards the other alkali halides. The solubility of potassium halides in potassium borates is slightly less than that in the corresponding sodium systems.

In the following paragraphs some of the more important borates shall be briefly discussed. Some of the phase relations have been worked out and again attention shall be called to the "Phase Diagrams of Interest to Ceramists" by F. P. Hall and Herbert Insley, published by the American Ceramic Society.

$Li_2O — B_2O_3$ • The exact phase relations of this system have not yet been worked out. A preliminary study of C. Mazzetti and F. De Carli (1926) indicates the existence of five lithium borates and gives approximately the following melting points:

$Li_2O \cdot B_2O_3$	760°C.
$Li_2O \cdot 2B_2O_3$	940°C.
$Li_2O \cdot 3B_2O_3$	760°C.
$Li_2O \cdot 4B_2O_3$	730°C.
$Li_2O \cdot 5B_2O_3$	700°C.

The optical properties of the lithium metaborate $Li_2O \cdot B_2O_3$ were determined by H. Le Chatelier (1897) and its melting point was found to be 843°C. by H. S. van Klooster.

$Na_2O — B_2O_3$ • The phase equilibrium relationships in this most important of the alkali borate system have been worked out by G. W. Morey and H. E. Merwin (1936). There were found the following five borates:

sodium orthoborate	$2\,Na_2O \cdot B_2O_3$	M.P. 625°C.
sodium metaborate	$Na_2O \cdot B_2O_3$	M.P. 966°C.
sodium diborate	$Na_2O \cdot 2B_2O_3$	M.P. 742°C.
sodium triborate	$Na_2O \cdot 3B_2O_3$	M.P. 766°C. (incongr.)
sodium tetraborate	$Na_2O \cdot 4B_2O_3$	M.P. 816°C. (incongr.)

In this work the orthoborate was discovered. It is of particular interest that sodium orthoborate can be quenched to a glass, whereas the metaborate, despite its higher B_2O_3 content, could not be obtained in vitreous condition. This is in marked contrast to the sodium silicates where the tendency toward crystallization increases regularly with their Na_2O content.

$K_2O — SiO_2$ • P. Rollet (1935) examined the system $K_2O — B_2O_3$ from 0 to 58% K_2O by means of heating curves. He mentions the following compounds:

potassium metaborate	$K_2O \cdot B_2O_3$	M.P. 950°C.
potassium diborate	$K_2O \cdot 2B_2O_3$	M.P. 815°C.
potassium triborate	$K_2O \cdot 3B_2O_3$	M.P. 825°C. (incongr.)
potassium tetraborate	$K_2O \cdot 4B_2O_3$	M.P. 857°C.
potassium pentaborate	$K_2O \cdot 5B_2O_3$	M.P. 790°C. (incongr.)

The potassium metaborate was previously described by F. M. Jaeger (1917). Its crystal structure indicates $(B_3O_6)^{3-}$ groups consisting of three BO_3 triangles interlinked in a way that two oxygens of each triangle belong to two BO_3 groups.

The potassium tetraborate was discovered by H. Le Chatelier in 1899.

$MgO — B_2O_3$ • The magnesium borate, $3MgO \cdot B_2O_3$, was described by Ebelmen, and the immiscibility gap in the system was studied by Guertler and by Foëx. More recently the phase relationships were worked out by N. A. Toropov and P. F. Konovalov (1940) as well as by H. M. Davis and M. A. Knight (1945). In the work of Davis and Knight, one finds a discussion of the previous work and of the discrepancies between their own findings and those of the Russian authors.

Davis and Knight investigated the system from 0.6% to 75% MgO and found the following three compounds:

$MgO \cdot B_2O_3$	M.P. 988°C. (incongr.)
$2MgO \cdot B_2O_3$	M.P. 1340°C.
$3MgO \cdot B_2O_3$	M.P. 1366°C.

The immiscibility region was found to extend from 0.6 to 36.0% MgO at 1142°C.

$CaO — B_2O_3$ • The phase diagram for this system has been partially worked out by E. T. Carlson (1932). His work served as a beginning of the phase studies in the important ternary system $CaO — B_2O_3 — SiO_2$. The following four compounds were found to exist:

$CaO \cdot 2B_2O_3$	M.P. 986°C.
$CaO \cdot B_2O_3$	M.P. 1154°C.
$2CaO \cdot B_2O_3$	M.P. 1298°C.
$3CaO \cdot B_2O_3$	M.P. 1479°C.

The optical properties of these compounds were determined. The region of immiscibility was found to extend from 0.3 to 23.0% CaO at 971°C. The immiscibility still exists above 1500°C.

$CaO — B_2O_3 — SiO_2$ • This ternary system is of fundamental importance in glass technology and ceramics because it may serve as a starting point for the development of borosilicate glasses, glazes and enamels. The phase relations were determined by E. P. Flint and L. S. Wells (1936). It is the first ternary system investigated to include both B_2O_3 and SiO_2 as components.

(*Continued on page* 158)

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BORIC OXIDE — ITS CHEMISTRY AND ROLE IN GLASS TECHNOLOGY . . .
(*Continued from page* 156)

In addition to the known calcium silicates and the above mentioned calcium borates, there are two ternary compounds. The pentacalcium borosilicate $5CaO \cdot B_2O_3 \cdot SiO_2$ M.P. 1419°C. was newly discovered, but the natural mineral danburite, $CaO \cdot B_2O_3 \cdot 2SiO_2$, was not obtained as a crystalline phase. Its composition is in the immiscibility portion of the monocalcium borate field.

The mineral danburite is the only known natural calcium borosilicate. Its melting properties were studied by G. W. Morey and Earl Ingerson (1936). The mineral remains unaffected by heating until 996°C., when sintering begins. When left for several days at 1002°C. the compound is entirely decomposed with formation of two liquid layers. The crystal is easily superheated. Synthesis was possible only by means of hydrothermal methods.

$PbO — B_2O_3$ • The system $PbO — B_2O_3$ was studied by R. F. Geller and E. N. Bunting, who found it to contain the following four compounds:

$4PbO \cdot B_2O_3$	M.P. 565°C.
$2PbO \cdot B_2O_3$	M.P. 497°C. (incongr.)
$5PbO \cdot 4B_2O_3$	M.P. 548°C.
$PbO \cdot 2B_2O_3$	M.P. 768°C.

The lowest melting eutectic has the composition 88% PbO and 12% B_2O_3. A narrow two liquid area extending from approximately 9 to 43% PbO was found to exist between 785°C. (for the crest having the composition 30.1% PbO and 69.9% B_2O_3) to 742°C.

W. Guertler reported immiscibility from 41 to practically zero PbO, a discrepancy which indicates how slowly the equilibrium is established in this region.

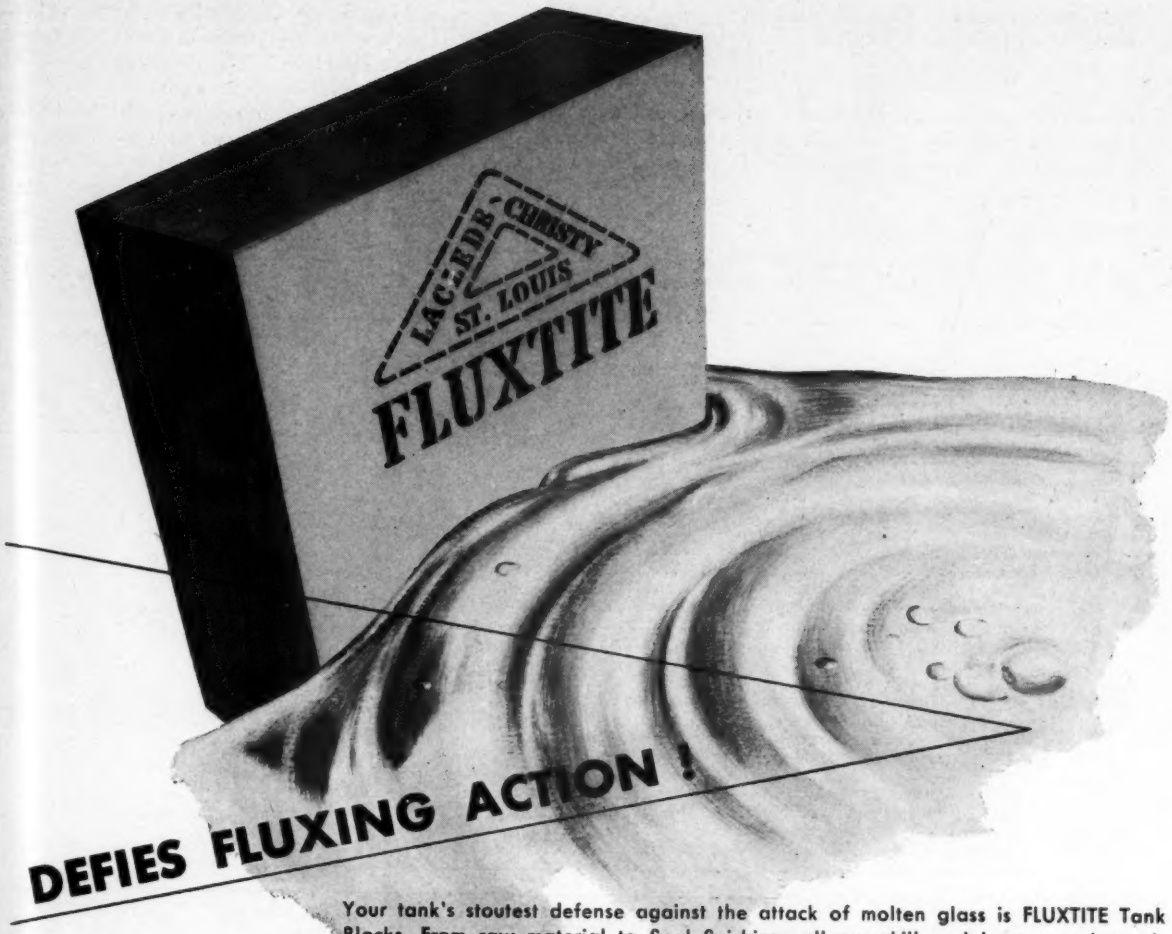
$PbO — B_2O_3 — SiO_2$ • This ternary system is of interest as a basis for developing low melting glasses and glazes as well as optical glasses of high refractive index. Phase relations were studied by R. F. Geller and E. N. Bunting (1939). A large portion of the diagram is covered by a two liquid area. One ternary compound was found, $5PbO \cdot B_2O_3 \cdot SiO_2$, which melts incongruently at 551°C. to form $2PbO \cdot SiO_2$ and a liquid. The liquidus of the lowest melting eutectic is at 484°C. and 84.5% PbO, 11.0% B_2O_3 and 4.5% SiO_2.

$CdO — B_2O_3$ • C. Mazzetti and F. De Carli studied the melting diagram of this system and found indications of the existence of two compounds, $CdO \cdot B_2O_3$ (M.P. 850°C.) and $CdO \cdot 2B_2O_3$ (M.P. 860°C.). Recently Th. P. J. Botden and F. A. Kröger (1947) studied the fluorescence of cadmium borates activated by manganese borates and report two more compounds, $2CdO \cdot B_2O_3$ and $3CdO \cdot B_2O_3$.

AUDIO-VISUAL MATERIALS CONSULTATION BUREAU FORMED

Wayne University in Detroit has established an Audio-Visual Materials Consultation Bureau as a service in the production of all types of instructional materials.

Companies and associations interested in making films, booklets, charts or specimen products available for school use may secure this service at the Bureau. Surveys showing school needs, critical analysis of scripts and copy and actual classroom try-out of materials in "rough" or finished form are types of help given.



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ECONOMIC PROBLEMS IN THE USE OF ALTERNATE FUELS . . .

(*Continued frob page* 140)

fication cost per ton of coal has been arrived at, exclusive of the cost of gas and steam coal. It is proposed to use the output of the producers as 1800° F. preheated raw producer gas.

XIII. Plant Investment

In order to determine a figure representing "Investment Handicap," it will be necessary to tabulate the investment in furnace, compressor plant, boilers and fuel system. Figure XIII is a tabulation showing plant investment. These figures are based on the following general plant layout: a) Large plant equipped with 2—10 foot producers; b) Medium sized plant equipped with 1—10 foot producer; c) Small plant equipped with 1—8 foot producer; d) Boiler plant cost based on $140.00 per BHP; e) Furnace cost includes stack, valves, piping, instrumentation but no foundations; f) Oil system for large plant includes 2—125,000 gallon and 2—30,000 gallon

(*Continued on page* 162)

FIGURE XII.
PRODUCER PLANT OPERATING COSTS

Plant	2—100 Ton Furnaces	2—55 Ton Furnaces	1—55 Ton Furnace
Number of producers	2—10 Foot	1—10 Foot	1—8 Foot
Coal gasified per 24 hours	70.3 Ton	41 Ton	20.5 Ton
% of Producer capacity	61.5%	71.9%	59.8%
Coal required to make steam per 24 hours	4.38 Ton	2.70 Ton	1.35 Ton
Operating cost per week:			
Producer and boiler operators @ $1.25 per hour	$210.00	$210.00	$210.00
Dust removal @ $1.00 per hour	32.00	16.00	16.00
Coal and ash removal @ $.10 per ton of coal	52.27	28.70	15.30
Burn-out every six days @ $1.00 per hour	8.00	8.00	8.00
Repair labor @ $1.65 per hour	13.20	6.60	6.60
Total labor per week	315.47	269.30	255.90
Total labor per ton of coal gasified	.641	.676	1.783
Power per week KW hour @ $.012	28.80	14.40	13.20
Repair materials, including coal, machinery, producers, auxiliaries, boilers, painting, etc., estimated during life of plant per week	60.00	30.00	30.00
Boiler feed water and producer cooling water based on recirculating water. 190 gallons per Ton of Coal @ $.10 per M gallon per week	9.35	5.45	2.73
Oil, waste, grease, supplies per week	6.00	3.00	3.00
Total cost of gasifying coal per ton, exclusive of coal	.852	.860	2.124
Cost of producer plant	$125,000.00	$95,000.00	$75,000.00
Depreciation at 10% per Ton of coal gasified	.488	.635	1.005
Total cost per ton of gasified coal including depreciation	$1.340	$1.495	$3.129

FIGURE XIII.
PLANT INVESTMENTS

	Natural Gas	Coke Oven Gas	Propane Butane	Light Oil Air Atomize	Light Oil Steam	Heavy Oil Air Atomize	Heavy Oil Steam	Hot 1800° F. Producer Gas
2—100 Ton Furnaces 18x32								
1536.8 Million BTU per 24 hours								
Furnace investment	$414,336.00	$414,336.00	$414,336.00	$414,336.00	$414,336.00	$414,336.00	$414,336.00	$504,000.00
Compressor investment	—	—	—	16,240.00	—	16,240.00	—	—
Boiler investment	—	—	1,960.00	—	9,240.00	6,020.00	14,000.00	—
Fuel System investment	15,000.00	15,000.00	40,200.00	75,000.00	75,000.00	90,000.00	90,000.00	125,000.00
Total investment	429,336.00	429,336.00	456,496.00	505,576.00	498,576.00	526,596.00	518,336.00	629,000.00
Total to natural gas investment	1	1	1.061	1.175	1.161	1.225	1.207	1.465
Investment handicap 6% per annum	—	—	$1,627.00	$4,574.00	$4,154.00	$5,835.00	$5,340.00	$11,979.00
Investment handicap per million BTU's	—	—	.0029	.00815	.00740	.0140	.00952	.0212
2—55 Ton Furnaces 16 x22								
849.96 Million BTU per 24 hours								
Furnace investment	$310,000.00	$310,000.00	$310,000.00	$310,000.00	$310,000.00	$310,000.00	$310,000.00	$364,000.00
Compressor investment	—	—	—	9,240.00	—	9,240.00	—	—
Boiler investment	—	—	2,240.00	—	5,320.00	5,200.00	10,290.00	—
Fuel System investment	12,000.00	12,000.00	24,600.00	60,000.00	60,000.00	68,500.00	68,500.00	95,000.00
Total investment	322,000.00	322,000.00	336,840.00	379.240.00	375,320.00	392,940.00	388,790.00	459,000.00
Total to natural gas investment	1	1	1.045	1.179	1.165	1.213	1.208	1.425
Investment handicap 6% per annum	—	—	890.00	3,434.00	3,199.00	4,376.00	4,007.00	8,220.00
Investment handicap per million BTU's	—	—	.0028	.01105	.0103	.0141	.0129	.0265
1—55 Ton Furnace 16x22								
424.98 Million BTU per 24 hours								
Furnace investment	$155,000.00	$155,000.00	$155,000.00	$155,000.00	$155,000.00	$155,000.00	$155,000.00	$182,000.00
Compressor investment	—	—	—	4,620.00	—	4,620.00	—	—
Boiler investment	—	—	1,120.00	—	2,660.00	4,200.00	6,860.00	—
Fuel System investment	6,000.00	6,000.00	18,600.00	57,000.00	57,000.00	65,000.00	65,000.00	75,000.00
Total investment	161,000.00	161,000.00	174,720.00	216,620.00	214,660.00	228,820.00	226,860.00	257,000.00
Total to natural gas investment	1	1	1.084	1.345	1.331	1.421	1.405	1.595
Investment handicap 6% per annum	—	—	823.00	3,337.00	5,366.00	4,069.00	3,951.00	5,760.00
Investment handicap per million BTU's	—	—	.00531	.0215	.0346	.0262	.0255	.0372

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** From "Westinghouse Engineer," May, 1946*

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ALTERNATE FUELS . . .
(*Continued from page* 160)

tanks; g) Oil system for medium and small size plant includes 1—125,000 gallon and 1—30,000 gallon tanks; h) Propane system includes 2—30,000 gallon tanks for

(*Continued on page* 164)

FIGURE XIV.
FUEL UNIT COSTS
2—100 TON FURNACE INSTALLATIONS

LOW HEATING VALUE INPUT REQUIRED 1536.8 MILLION BTU's PER 24 HOURS

	Natural Gas	*Coke Oven Gas*	*Butane*	*Propane*	*Light Oil Air Atomize*	*Light Oil Steam*	*Heavy Oil Air Atomize*	*Heavy Oil Steam*	1800° *F.*	*Producer Gas*
Fuel for one million net BTU's.	1106 C.F.	2146 C.F.	10.83 gal.	11.93 gal.	7.61 gal.	7.81 gal.	7.18 gal.	7.28 gal.	Gas coal 91.5‡	Steam coal 5.67‡
Atomization Air	—	—	—	—	$.02660	—	$.02770	—	—	—
Atomization Steam	—	—	—	—	—	$.02142	—	$.02210	—	—
Fuel System—Dep. repairs and insurance 15%	.00401	.00401	.01075	.01075	.02000	.02000	.02400	.02400	—	—
Preheating and unload steam.	—	—	.00825	.00901	—	—	.00821	.00835	—	—
Fuel pumping and unloading power and labor	—	—	.00590	.00650	.00472	.00485	.00446	.00452	—	—
Gasification cost includes repairs, insurance and depreciation	—	—	—	—	—	—	—	—	.06120	—
Investment Handicap	—	—	.00290	.00290	.00815	.00740	.01400	.00952	.02120	—
Total Cost per Million Low Heating Value BTU's ...	.00401	.00401	.02780	.02916	.05947	.05367	.07837	.06849	.08240	—
Unit Fuel Quantity	1000 C.F.	1000 C.F.	100 gal.	100 gal.	100 gal.	100 gal.	100 gal.	100 gal.	1000‡	62‡
Total Cost per Unit Fuel ...	.00362	.00182	.2566	.2447	.7814	.6875	1.090	.9400	.9005	—

FIGURE XV.
FUEL UNIT COSTS
2—55 TON FURNACE INSTALLATIONS

LOW HEATING VALUE INPUT REQUIRED 894.96 MILLION BTU's PER 24 HOURS

	Natural Gas	*Coke Oven Gas*	*Butane*	*Propane*	*Light Oil Air Atomize*	*Light Oil Steam*	*Heavy Oil Air Atomize*	*Heavy Oil Steam*	1800° *F.*	*Producer Gas*
Fuel for one million net BTU's.	1.106 C.F.	2.146 C.F.	10.83 gal.	11.93 gal.	7.61 gal.	7.81 gal.	7.18 gal.	7.28 gal.	Gas coal 91.5‡	Steam coal 5.67‡
Atomization Air	—	—	—	—	$.02660	—	$.02770	—	—	—
Atomization Steam	—	—	—	—	—	$.02142	—	$.02210	—	—
Fuel System—Dep. repairs and insurance 15%	.00551	.00551	.00113	.00113	.02750	.02750	.03140	.03140	—	—
Preheating and unload steam.	—	—	.00825	.00901	—	—	.00821	.00835	—	—
Fuel pumping and unloading power and labor	—	—	.00590	.00650	.00472	.00485	.00446	.00452	—	—
Gasification cost includes repairs, insurance and depreciation	—	—	—	—	—	—	—	—	.0685	—
Investment Handicap	—	—	.00280	.00280	.01105	.01030	.01410	.01290	.0265	—
Total Cost per Million Low Heating Value BTU's ...	.00551	.00551	.02465	.02601	.06987	.06407	.08587	.07927	.0950	—
Unit Fuel Quantity	1000 C.F.	1000 C.F.	100 gal.	100 gal.	100 gal.	100 gal.	100 gal.	100 gal.	1000‡	62‡
Total Cost per Unit of Fuel..	.00497	.00497	.2295	.2282	.917	.820	1.208	1.089	1.040	—

FIGURE XVI.
FUEL UNIT COSTS
1—55 TON FURNACE INSTALLATION

LOW HEATING VALUE INPUT REQUIRED 447.48 MILLION BTU'S PER 24 HOURS

	Natural Gas	*Coke Oven Gas*	*Butane*	*Propane*	*Light Oil Air Atomize*	*Light Oil Steam*	*Heavy Oil Air Atomize*	*Heavy Oil Steam*	1800° *F.*	*Producer Gas*
Fuel for one million net BTU's.	1106 C.F.	2146 C.F.	10.83 gal.	11.93 gal.	7.61 gal.	7.81 gal.	7.18 gal.	7.28 gal.	Gas coal 91.5‡	Steam coal 5.67‡
Atomization Air	—	—	—	—	$.02660	—	$.02770	—	—	—
Atomization Steam	—	—	—	—	—	$.02142	—	$.02210	—	—
Fuel System—Dep. repairs and insurance 15%	.00551	.00551	.01710	.01710	.05230	.05231	.05970	.05970	—	—
Preheating and unload steam.	—	—	.00825	.00901	—	—	.00821	.00835	—	—
Fuel pumping and unloading power and labor	—	—	.00590	.00650	.00472	.00485	.00446	.00452	—	—
Gasification cost includes repairs, insurance and depreciation	—	—	—	—	—	—	—	—	.1430	—
Investment Handicap	—	—	.00531	.00531	.02150	.03460	.02620	.02550	.0372	—
Total Cost per Million Low Heating Value BTU's ...	.00551	.00551	.03656	.03792	.10512	.11318	.12627	.12017	.1812	—
Unit Fuel Quantity	1000 C.F.	1000 C.F.	100 gal.	100 gal.	100 gal.	100 gal.	100 gal.	100 gal.	1000‡	62‡
Total Cost per Unit of Fuel..	.00497	.00257	.3370	.3175	1.380	1.450	1.760	1.650	1.980	—

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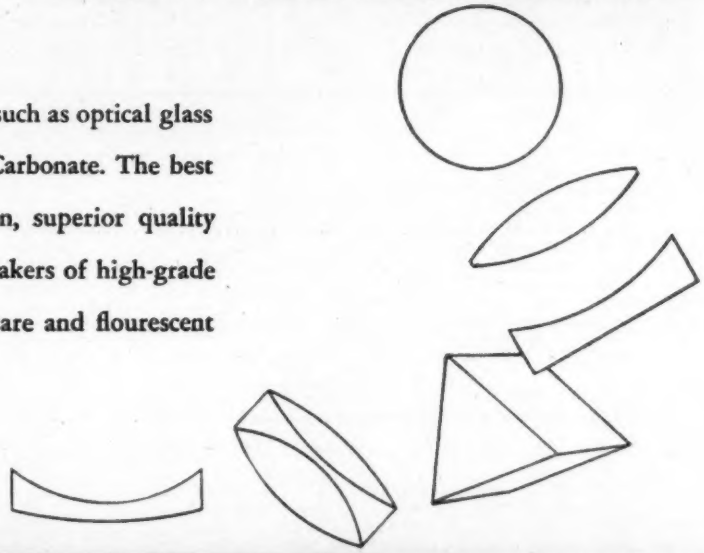

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ALTERNATE FUELS . . .
(*Continued from page* 162)

large plant and 1—30,000 gallon tank for medium and small size plane; and i) Compressor plant cost is based on $20.00 per CFM of rated capacity.

XIV. Summary of Fuel Costs per Million BTU's of Low Heating Value Fuel

The tabulations shown in Figures XIV, XV and XVI attempt to summarize and place in convenient form all pertinent data pertaining to the operation of a large, medium and small plant. With the information available, it will be possible to make an evaluation of all fuels. A sample calculation will be presented to show the manner in which the accumulated data can be used.

XV. Sample Calculations

The following sample calculations will serve to illustrate the use of the data assembled.

"Gas Coal is available at $7.50 per ton delivered. Steam Coal is available at $6.00 per ton delivered. Stack Temperature 1,000° F.

What is the equivalent fuel cost if operation is to be on heavy fuel oil using steam for atomization. Calculation will be made for three types of plant installations.

a) Plant with 2—100 Ton Furnaces
b) Plant with 2— 55 Ton Furnaces
c) Plant with 1— 55 Ton Furnace

Calculations have been tabulated in Figure XVII.

XVI. Conclusion

It has been attempted in this paper to set forth an outline of procedure to enable a rational analysis to be made of comparative fuel costs. The outline that has been presented will permit adaptation to any set of local conditions. It is evident that for an accurate analysis, each specific installation must be given individual consideration.

FIGURE XVII.
SAMPLE CALCULATIONS

Plant Size	"A"*	"B"*	"C"*
Coal for 1,000,000 BTU of useful heat			
Steam Coal 5.67# @ $6.00/T. (Fig. IX)	$.01701	.01701	.01701
Gas Coal 91.5# @ $7.50/T. (Fig. IX)	.34312	.34312	.34312
Coal Processing (Fig. XIV)	.08240		
Coal Processing (Fig. XV)		.09500	
Coal Processing (Fig. XVI)			.18120
a.) Total of above per 1,000,000 BTU	.44253	.45513	.54133
b.) Correction for 1,000° F. Stack (Fig. X) and 1% allowance for reversal loss. $\frac{1}{1-.275} \times 1.01$	1.39	1.39	1.39
c.) Corrected Coal Cost (a x b)	.61491	.63262	.75244
d.) Oil for 1,000,000 BTU of useful heat (Fig. IX)	7.28 Gal.	7.28	7.28
e.) Correction for 1,000° F. Stack (Fig. X) $\frac{1}{1.20}$	1.25	1.25	1.25
Corrected oil required (d x e)	9.100	9.100	9.100
f.) Oil Processing 9.100 x $.00940 (Fig. XIV)	.08554		
f.) Oil Processing 9.100 x $.01089 (Fig. XV)		.09909	
f.) Oil Processing 9.100 x $.01650 (Fig. XVI)			.15015
Equivalent cost of 9.10 gal. of oil (c-f)	.52937	.53354	.60229
Equivalent cost of oil per gal. on siding	$ .0581	.0586	.0662

*"A—2—100 Ton Furnace Plant.
*"B—2— 55 Ton Furnace Plant.
*"C—1— 55 Ton Furnace Plant.

DR. HOSTETTER MADE HONORARY MEMBER OF KERAMOS CHAPTER

The Missouri School of Mines Chapter of Keramos has initiated Dr. John C. Hostetter as their first honorary member. At the same time, three others were read the ritual, one of whom was a new member, B. C. Giltner.

A banquet was held, after which Dr. Hostetter spoke to a group on the "History of Glass."

M. A. DU BOIS DIES

It has been learned that Merlin A. DuBois, Vice President in Charge of Sales of the Fostoria Glass Company, has passed away.

Mr. DuBois has served this organization for many years and by his many activities had won the respect of the industry. He is survived by his wife, Frances, and three daughters.

AGA TO EXHIBIT IN FOUNDRY SHOW

The Industrial and Commercial Gas Section of the American Gas Association will sponsor an exhibit in the 52nd Annual Convention and Foundry Show to be held May 3-7, 1948.

This is the first time A.G.A. has participated in a Foundry Show, and the decision was made because of the widespread application of gas in this field.

CAMBRIDGE WIRE NAMES SALES ENGINEER

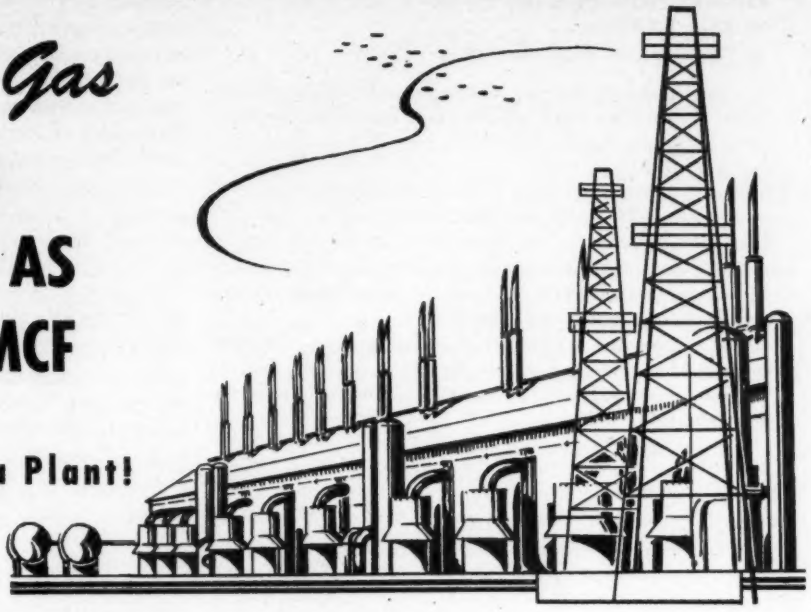
The Cambridge Wire Cloth Company has announced the appointment of Howard E. Claycombe as Sales Engineer in charge of their Chicago office.

Mr. Claycombe has assumed his new duties and is located at 332 South Michigan Blvd., Chicago 4, Illinois.

Natural Gas

RATES AS LOW AS 10c per MCF

. . . in an Oklahoma Plant!



Based on the national average of 21.4c per MCF for all other gas consuming states in the nation, a glass plant in Oklahoma saves 11.4c per MCF on fuel cost, which in glass manufacturing amounts to 6.05% of the production cost. Further, there's no shortage. Oklahoma is in the center of 74% of the nation's proven reserves.

But lower gas costs aren't all. Coal is native, and so is high quality glass sand, dolomite, and limestone. Right next door are feldspar, borax and soda ash, and numerous machine shops and fiber box manufacturers.

Corporate laws have been revised a la Delaware, and income taxes reduced 1/3 with full exemption for federal taxes.

No wonder Oklahoma's "OK" for the glass industry. Why not write and find out ALL* about it?

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CONVECTION CURRENTS IN A GLASS TANK . . .
(*Continued from page* 143)

flow of the liquid drawing in the same direction is none other than the area beneath the right side which we have previously calculated; it is $C/4h_1^4$, or, in introducing the depth h_0 of the bath:

$$(29) \qquad \Phi_1 = 0.0295\ Ch_0^4 = \frac{Ch_0^4}{34}$$

The flow is, therefore, about two times as strong as that which was calculated in (14) for the same height of passage h_0 and for an effective length l.

The simple act of introducing friction on the free surface of the bath, for example, by a slightly sunken barrier (skimmer), visibly reduces the thermal changes by convection.

The amount of heat transported is here:

$$(30) \qquad Q = \frac{C\rho_0 gkL}{200\eta l}(\Theta_1 - \Theta_2)^2 h_0^4$$

It is still proportional to the square of the difference of temperature and to the fourth power of the depth of the bath.

f. *Passage to the actual bath.* In the preceding discussion, it was assumed that the temperature was uniform in each dynamic column, which involved the independence of the density and of the viscosity upon the depth.

In the case of a glass bath, particularly, this is grossly inexact. In a normal furnace, heated by flames above the bath and having a tank of one meter of depth, the bottom is at a temperature about 150°C. lower than that existing on the surface. This fall of temperature is of the same order of magnitude as that which exists between the two extremities of the same tank compartment. We cannot, therefore, *a priori*, neglect it.

Concerning the variation of density with the vertical gradient of temperature, the calculation shows* that this variation has relatively little action on the dynamic pressure, such as that shown in (5).

If the dynamic pressure remains practically unchanged, in spite of the temperature gradient, it is not thus for the viscosity, η, which is involved in all the expressions of speed or of heat flow. The latter passes from 100—1000, for example, between the surface and the bottom of the tank; it is therefore evident that the curve of speeds, such as that determined in Figure 27, must be modified.

We could anticipate the introduction of an exponential law of variation of the viscosity with the depth. This would highly complicate our calculations without much profit; indeed, we are seeking a theoretical explanation of the phenomena, for drawing equations of the *indications*, but not rigorous conclusions.

We can formulate, without calculation, an idea of the influence of the variation of viscosity. As the friction of the deep layers increases, the curve of speeds must be compressed towards the top, as indicated in Figures 29 *a* and *b*. The neutral line is situated higher than is indicated in the theory, and as much higher, as the surface is more fluid. In the bottom must exist a stagnant layer, which is a bed of almost motionless glass. *The "effective" height is lower than the geometric height.*

In the light of pictures which we have made, we are going to draw practical conclusions in the following chapter, and make conjectures on the behavior of the glass in in the furnace chambers, comparing them, whenever possible, with the experimental results of the second part.

*The equation (5) transforms into:

$$P = \rho_0 gk(\Theta_1 - \Theta_2)h_0$$

$$(31) \quad X\left[1 + \frac{\alpha\Theta_1 h_1 - \beta\Theta_2 h_2}{\Theta_1 - \Theta_2} - \frac{\alpha\Theta_1 - \beta\Theta_2}{\Theta_1 - \Theta_2} \cdot \frac{h_0}{2}\right]$$

(α and β characterizing the vertical variant of temperature in the hot and cold compartments; h_2 and h_1 being the respective heights at the time of dynamic equilibrium). Taking account of the orders of magnitude of the coefficients, this expression is simplified and becomes:

$$(32) \quad P_0\left[1 + \frac{a}{2}(2h - h_0)\right]$$

which differs from ρ_0 at most by only 10%. The equation (5) thus sufficiently represents reality.

INVENTIONS AND INVENTORS . . .
(*Continued from page* 149)

closed in Patent No. 2,312,245 to John Flaws.

At station A the operator places the mount 13 on the upper end of the spindle 15 and at station B inserts the bulb 14 in its holder as shown in the sectional view. Station C is usually an idle station. In passing to station D, the head first passes out of engagement with a track 47 which has held the head from turning away from the operator, and then into engagement with a moving chain 48 which starts the head rotating. It will be seen that the head is held from rotation at stations P, Q, A, B, and C. At stations D and E burners 62 and 63 direct a soft flame against the flared stem tube 21 and to the lower end of the bulb 14. Stations F, G, H, J, K, L and M are provided with high temperature burners 64 which may use a fuel made from natural gas and oxygen. When the head reaches station H the parts have been heated so when a sleeve 65 is elevated, the parts are moved into intimate contact. At station J a second upward movement of the sleeve 65 unites the parts, forming an annular ridge 86 on the bottom of the lamp.

At stations K, L and M the heating of the parts is continued so that they are securely fused together. Stations N and O are provided with low heat burners which act to anneal the parts and to allow them to cool to the extent where they will stand room temperature. When the head leaves station O the sprocket 54 moves out of contact with the chain 48 so that rotation of the lamp is stopped and at the same time a roller 52 enters the track 47 so that the parts are held in position for removal of the work. Station P is a cooling position so that the lamp may be removed at station Q.

The following references are of record in the file of this patent: United States Patents: 1,475,192, Marshall, Nov. 27, 1923; 1,924,532, Zimber et al., Aug. 29, 1933; 2,063,235, Eisler, Dec. 8, 1936; 2,185,704, Donovan et al., Jan. 2, 1940; 2,203,917, Malloy, June 11, 1940; 2,268,510, Kulberg et al., Dec. 30, 1941; 2,335,617, Thomas et al., Nov. 30, 1943; 2,349,822, Gardner, May 30, 1944; 1,788,957, Phelps, Jan. 13, 1931; 1,842,184, Madden, Jan. 19, 1932; and 2,162,209, Trutner, June 13, 1939.

GOODRICH DEVELOPS GLASS FABRIC CONVEYOR BELT

The development of a hot material conveyor belt using glass fabric instead of the cotton fabric used in the conventional belt made for this service has been announced by The B. F. Goodrich Company.

The company suggests for this use two weights, a four-ply for light service and a five-ply for wider, longer belts where working stresses will be somewhat higher than in the light service. Covers recommended are either a 5/32 inch top and 1/32 inch back or a 3/16 top and 1/32 back, depending on operating conditions. Included in the belt's top cover will be a ply of longitudinal nylon breaker which, to give best protection, is floated 1/32 inch above the carcass.

The announcement further states that the tensile strength of each ply of glass fabric is approximately equal to the standard 32 ounce cotton fabric used in conventional belts. The advantage of glass fabric for this service is its resistance to loss of carcass strength under high temperatures. Cotton fabric loses strength rapidly under these severe operating conditions.

One experimental belt, which was installed on a short conveyor for carrying hot molding sand from below a foundry shapeout machine, was on 888 hours before the test was terminated and the belt removed for inspection. Normal service given by a conventional cotton fabric belt in the same service was 456 hours.

In another test, a glass fabric belt carrying hot lime ranging in temperatures from 300 to 450 degrees Fahrenheit was in service a year before removal for inspection, while the best record accomplished by a conventional cotton fabric belt on this conveyor had been seven months.

CANADA WITHDRAWS "AUSTERITY" TAX

Of interest to the glass industry is the report that the Canadian Government has decided to withdraw the new 25 per cent "austerity" tax on a group of articles, including certain types of mirrors, with this action having been taken because it was feared that some of Canada's own export trade was threatened.

Originally, the tax was aimed at cutting down sales of imported goods, but officials said that in these lines, it was threatening to backfire upon similar items manufactured in Canada and sold in the United States.

ONE-WAY BEER BOTTLE TESTS

Containing instructions to possible finders in eight different languages, 100 bottles were scattered across 6,000 miles of the Pacific in a scientific test of sea currents. The purpose of the undertaking is to help verify the movement of ocean current and to test the durability of the one-way beer bottle.

The bottles, in groups of five, were dropped from an airliner at 20 pre-arranged locations. Average altitude at which bottles were dropped was 9,000 feet.

Each bottle, securely corked and sealed with wax, contains a printed slip with the black type heading: Important, Please Read Carefully! Below are instructions in English and seven other languages for mailing the bottle back to the sender.

FOR SALE

GLASS PLANT, CHICAGO HEIGHTS, ILLINOIS

By order of the United States District Court for the Northern District of Ohio, Western Division, Owens-Illinois Glass Company offers for sale as a unit all real estate, buildings, machinery, production equipment (not including molds), tanks and furnaces (except experimental machinery and furnaces) located at Chicago Heights, Illinois, and which were a part of the assets acquired by Owens-Illinois Glass Company from Kimble Glass Company on July 1, 1946.

In accordance with the order of the Court such property is offered for sale for cash to any purchaser approved by said Court, subject to prior sale, at the fair market value of said property as a glassware manufacturing plant, as determined by an appraisal made by The Lloyd-Thomas Company, which said appraisal has been duly filed with the Clerk of said Court at Toledo, Ohio., where it may be inspected. Additions and improvements made to the property described above since July 1, 1946, and prior to consummation of sale are not included in the appraised value aforesaid but are offered for sale as a part of the unit for an additional consideration equal to the cost thereof to Owens-Illinois Glass Company.

In connection with the sale of the property and additions and improvements thereto above described, Owens-Illinois Glass Company will assign or cause to be assigned to the purchaser thereof for the consideration hereinafter set forth, all its rights in and to the following machinery and equipment leased from Hartford-Empire Company situate on said premises on July 1, 1946, to-wit:

4—4 head I S machines with feeders, revolving tube drives and motors, and variable speed drives and motors

1—5 head I S machine with same

2—36" x 74' lehrs, gas fired with top vertical discharge, motor driven steel plate exhaust fan, and all regular equipment

The consideration to be paid by the purchaser to Owens-Illinois Glass Company for the assignment of its rights in the leased machinery aforesaid shall be cash in such an amount as will reimburse Owens-Illinois Glass Company for a fair proportion of any and all payments made in connection with said leased machinery by Kimble Glass Company or Owens-Illinois Glass Company which may be considered as costs of installation, advance payments for minimum annual royalties, license fees, parts, insurance and taxes.

In the event of such sale, possession will be delivered not later than six months after the consummation of such sale to a purchaser approved by the said Court.

Address all inquiries to

Owens-Illinois Glass Company
Attention: F. G. Morfoot
P. O. Box 1035, Toledo 1, Ohio

(*Continued from page* 146)

also if in equation (2) W is the breaking load and $\frac{l}{\Delta l}$ the relative total elongation; 108 values of E have been obtained in this way. Three of these values were below 600 kilobars, 26 between 600 and 700, 36 between 700 and 800, 28 between 800 and 900, 10 between 900 and 1000, and 5 above 1000 kilobars. The mean value of E in this series was 763 kilobars. The average length of the specimens (single filaments) was 16.2 cm. The average tensile strength was 23.1 kilobars (235 kg.-weight/sq.mm. or 334×10^3 lb./sq.in.).

Out of 108 values obtained in this series for the total elongation, 66 were confined within the range 2.6-3.6 per cent, and the average was 3.09 per cent.

Evaluation of the Results

The absolute values. The absolute values of the tensile strength found in this work generally agree with those of previous observers.

Griffith[6] measured the tensile strength of the strongest piece about 1.25 cm. long, of 15 cm. long fibers*; his values ought to be therefore somewhat higher than the highest values in Table I which had been determined on fibers 4.5 cm. long. The strength recorded in Table I is 268 kg.-weight/sq.mm. or 26.3 kilobars, and an interpolation of Griffith's data gives for fibers of 5.35×10^{-4} cm. in diameter a value near 280 kg.-weight/sq.mm. or 28.5 kilobars.

Anderegg[1] tested commercial fibers of the same type as those used in the present work. He found the range of strength values of 200-300 kg.-weight/sq.mm. or 20-30 kilobars, the specimen length being 1 cm.

In some recent investigations[4, 8, 10] larger fibers (over 12×10^{-4} cm. in diameter) were used so that their results cannot easily be compared with ours.

The scatter of the data summarized in Table I is great but not much greater than that observed for some other glass goods. The standard deviations listed in Table I are equal to 18 per cent, 17 per cent, and 28 per cent of the mean. In a sample of 1000 glass bottles the relative standard deviation was 11 per cent.[11] Batches of 10 bottles in the 1000 bottle sample gave means varying from 560 to 385, i.e., in the ratio 1 : 1.46. Table II shows that in a sample of 260 specimens of a continuous thread the analogous variation was from 457 to 376, i.e., the ratio of the extreme values was 1.22. In the whole sample of 260 threads (Table II) the highest breaking load was 495, and the lowest 345. The ratio of these values is 1.43. Murgatroyd[10] found for less extensive samples of single filaments, 25×10^{-4} cm. thick, the analogous ratio to be 10. His specimens were hand made.

As pointed out in the Introduction above, the absolute value of the modulus of elasticity is important for understanding the mechanical properties of glass fibers. The modulus of elasticity of glass rods and plates usually varies between 600 and 800 kilobars.[9] The effect of the chemical composition is not very pronounced so that it is highly probable that Young's modulus, also of the alkali-free glass employed for fiber-drawing, has a similar magnitude (for big specimens). The mean moduli listed in Table IV, i.e., 733 and 812 kilobars, agree quite well with those determined on bulkier specimens. The *mechanical* theory of fiber strength appears to be vindicated by this result.

Anderegg[1] determined the modulus of elasticity of filaments 13×10^{-4} cm. thick and obtained values between 200 and 400 kilobars; they generally increased with the length of the specimen. A slight rise of modulus E with the specimen length is visible also in Table IV, but too much importance should not be attached to this observation. As pointed out in the section on Experimental Procedure, the main errors in determining E tend to lower its value, and are relatively more important the shorter the filament.

Murgatroyd[10] computed E from bending of single filaments which had been drawn by hand; that is, both his material and his experimental technique were different from ours. That may account for the difference between his results and ours. In Murgatroyd's experiments E was near 600 kilobars for fibers thicker than 50×10^{-4} cm. but rapidly decreased when the fiber diameter diminished and was about 400 kilobars for diameters of about 15×10^{-4} cm. Extrapolation of Murgatroyd's curve to the diameter of 5.7×10^{-4} cm. would give a modulus of elasticity below 300 kilobars, i.e., less than half of that found in the present work. We carried out no experiments on filament bending and cannot form a definite opinion on Murgatroyd's observations, but it appears that also in the bending method higher E values are less likely to be due to experimental difficulties than are the low ones.

The effect of the specimen length. The theoretical importance of this effect has been pointed out in the Introduction above.

Tables II and III allow the decision to be made on whether the length affects the strength only because of the higher probability of a weak spot in a longer specimen. If a thread 50 cm. long is cut into ten 5 cm. long pieces, one of these segments must contain the weakest spot of the original thread and break at the same stress as would the 50 cm. long specimen. That means that, on the average, the lowest breaking load observed in a batch of 10 specimens 5 cm. long should be identical with the breaking load of 50 cm. long specimens. In other words, the values in the 4th column of Table II should not be significantly different from those in column 5, and there should be no significant difference between columns 2 and 3 of Table III.

A check of whether two series of numbers are or are not significantly different can be performed as follows[5]: Let x be the difference between the mean values, that is, for Table III between 388 and 386, and $x_1, x_2, \ldots$ the differences between two values on one line, e.g., 365-360 on the first line of Table II and 427-394 on the first line of Table III. Let the number of observations (26 for Table II, 9 for Table III) be n. Then

$$t = \frac{x\sqrt{n\,(n-1)}}{[(x_1-x)^2 + (x_2-x)^2 + \ldots + (x_n-x)^2]^{\frac{1}{2}}} \qquad (3)$$

is a measure of the significance. Table II gives $t = 0.9$, and Table III, $t = 0.2$. According to R. A. Fisher in a sample of 26 observations the probability of t being 0.9 by chance is 0.4; and in the sample of 9 observations t is equal to 0.2 by chance in 8 cases out of 10. Consequently,

*Brown, Mann and Pierce[8] showed that the breaking strength of a cotton hair increased three times when the hair was broken in tension 5 times, thus eliminating the four weakest spots.

the differences between the two columns in Tables II and III are not significant, and the breaking load of the weakest part of a thread is equal to that of the whole thread. That is another confirmation of the *mechanical* theory of the fiber strength.

REFERENCES

1. Anderegg, F. O., Ind. Eng. Chem. *31*, 290 (1939).
2. Bikerman, J. J., J. Soc. Chem. Ind. *60*, 23 (1941).
3. Brown, K. C., Mann, J. C., and Pierce, F. T., J. Text. Inst. *21*, T 186 (1930).
4. Burov, A. K., et al., J. Tech. Phys. (U.S.S.R.) *15*, 425 (1945).
5. Fisher, R. A., "Statistical methods for research workers," 8th ed., p. 120, Edinburgh, Oliver & Boyd, 1941.
6. Griffith, A. A., Phil. Trans. Roy. Soc. A *221*, 163 (1920).
7. Kontorova, T. A., J. Tech. Phys. (U.S.S.R.) *15*, 436 (1945).
8. Krotova, N., J. Tech. Phys. (U.S.S.R.) *14*, 455 (1944).
9. Morey, G. W., "The properties of glass," pp. 293-319, New York, Reinhold Publishing Corp., 1938.
10. Murgatroyd, J. B., J. Soc. Glass Tech. *28*, 368 (1944).
11. Preston, F. W., J. Am. Ceram. Soc., *20*, 329 (1937).
12. Rexer, E., Z. tech. Physik, *20*, 4 (1939).

CANADIAN GLASS REPORT

Canadian imports of glass and glassware rose sharply during the past twelve months, according to the latest annual report of the External Trade Branch of the Canadian Government, showing that during 1947 such imports totalled $28,626,000 compared with $23,258,000 in the similar twelve months of the preceding year. However, the effects of the newly announced import restrictions apparently showed up towards the end of 1947 since imports of glass and glassware in December dropped to $1,669,000 in 1947, compared with $2,084,000 during December 1946.

Nevertheless, the Canadian market for glass and glassware is evidently much greater than in pre-war years since postwar imports are running far ahead in value, with this official report emphasizing that in the last complete pre-war year, 1938, Canadian imports of such items had totalled only $6,670,000.

GLASS AMPULE PATENTS MADE AVAILABLE

Attorney General Tom C. Clark has announced that 24 patents on the manufacture of glass ampules and related processes have been made available for licensing by the Office of Alien Property, Department of Justice.

The patents also cover apparatus for forming inner threads on containers and the sorting, filling and stencilling of glass containers. Licenses on these patents are available on a royalty-free, non-exclusive basis for an administrative fee of $15.00 per patent.

A list of the 24 patents and complete licensing information can be obtained without cost from the Office of Alien Property, Department of Justice, Washington 25, D. C. Copies of the patents may be purchased from the Commissioner of Patents, Washington 25, D. C., at twenty-five cents each.

GOODRICH TO CONSTRUCT CHEMICAL PLANT

B. F. Goodrich Company will construct a new $3,000,000 general chemical plant in Avon Lake, Ohio, according to a recent announcement.

The new plant will be located on the tract owned by the company in Avon Lake, where its chemical experimental station is already located. Various general chemical products now in the development or semi-commercial stage will be produced.

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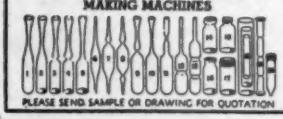

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WORKERS IN WINDOWLESS FACTORIES . . .

(*Continued from page* 147)

human beings will, for any length of time, remain contented in any environment to which natural light is not admitted. A windowless work area can with electric light be as bright, or brighter, than day during daylight hours; yet prove to the occupants as dark as any moonless or starless night. Cases cited earlier in this article will substantiate this statement.

On the wrong trail, is the engineering company with its self-styled "Controlled Conditions" plant—completely windowless. In the portfolio presentation of the plan, there is nothing said about workers being deprived of daylight during a normal work shift. Technical improvements in glassed areas are reviewed in guarded or skeptical terms. For example,

Glass Blocks: Page seven of the portfolio contains a "has been" reference in that "it has served a useful purpose. But with these types of side wall fenestration, best conditions are obtained only when glare and heat rays are controlled." However, on page eight, there is this admission: "The use of glass blocks does eliminate the transmission of dust and fumes from the outside, but in the summertime they do absorb and re-radiate heat."

Another allusion to glass blocks is to be found on page twelve; "They serve a useful purpose. However, in summertime, the glass block has a tendency to store the solar load and re-radiate the heat into the interior of the building, thus normally maintaining higher indoor temperatures when the building interior would normally be cooling off."

Double or "Sandwich" Windows: This recent type of construction is dismissed with the statement that . . . "it does reduce heat loss, and with the use of polarized glass or venetian blinds, glare can be eliminated, but with a corresponding loss in daylight intensity."

Weather Control: The report asserts that "for years attempts to alleviate this condition by means of fans, awnings, venetian blinds—and, more recently—continuous solar canopies on the exterior—have met with only partial success."

Saw Tooth Roof Construction: The controlled conditions plant advocates make the following admissions: "This design is sometimes advocated as a good type to provide a more even distribution of daylight throughout the entire factory area. With the sash facing north, glare is eliminated on bright days, but on dull days not enough natural light is provided. In cold climates, snowfall in the valley of the saw-tooth may sometimes block off as much as fifty per cent of the glass area. Unless proper precautions are taken, condensation will result regardless of the climate."

This Writer's Analysis: With the single exception of the saw-tooth roof construction, the controlled conditions plant advocates review natural lighting conditions from the summer heat standpoint. In other seasons, particularly winter, it is desirable in northern locales to "trap" the fullest amounts of natural light and solar heat.

This report also claims that in winter artificial lighting in a windowless factory reduces absenteeism due to colds and other respiratory diseases.

Factual evidence to the contrary is furnished by the British Industrial Research Board. Repeated tests made in windowless plants which introduced artificial sunlight

treatment of workers failed to reduce the seasonal crop of common colds.

Any skeptical-minded readers should purchase a copy of His Majesty's Stationery Office (it corresponds to our federal Superintendent of Documents) paper-backed pamphlet, "Artificial Sunlight Treatment in Industry," officially listed as Industrial Health Research Board Report No. 89. It has pathos, humor, and other human nature insights in the reactions of British factory workers to improve on the fickle British climate with a mechanized semi-medical aid.

Dr. Dora Colebrook, author, frankly admits that British sunlight in winter is an elusive element. What there was in it during World War II winters was kept out by the twenty-four hour blackout of factories. While this blackout was officially regulated to hours between dawn and dusk, most factory owners, to save time and effort in the twice daily change-over, applied black paint and other concealment materials and devices to their glassed areas.

Not only were workers depressed and frustrated (claustrophobia), but common colds and other ills took quite a jump during the winter months. Hoping to reduce absenteeism, many industrialists installed quartz mercury arc lamps. Small groups of workers received this irradiation of the body treatment during daily sessions.

It takes 63 pages of small type in this British Government sponsored booklet to prove that the introduction of artificial sunlight treatment does not build up a resistance to common colds and other ills.

"Natural lighting, when there is enough of it, is ideal," states the Medical Research Council of the British Industrial Research Board.

A reaction oddity to the British wartime black-out was that industrial workers complained of poor ventilation, even when that ventilation was adequately controlled by artificial and mechanized means.

Such complaints were rife in plants which blackened their windows so that not a ray of daylight could enter.

On the other hand, plants with free entry of daylight, with late afternoon installations of black screens and curtains, and removal of the same shortly after dawn, had no such complaints.

Ventilation in both types of plants was identical.

What is the explanation? It is found in a British document on "The Problem of Absenteeism." The summary states that "workers in a permanently blacked-out factory complain that they get a feeling of depression owing to the absence of sunlight. They are also inclined to feel that proper ventilation is lacking because they do not feel the movement of air on their faces."

The British Ministry of Works, and certain other governmental agencies, know a lot about artificial lighting. It was, during World War II, indispensable to British Industry. *It still is.* Windowless factories are not, however.

The British Ministry of Health, an allied agency, makes the sensible admission that "the admission of daylight has a psychological value, and we would strongly deprecate the entire omission of natural light from premises used for continuous working occupation."

• The production of glass containers of all kinds is expected to get under way within the near future at the new Hazel-Atlas Glass Company plant in Montgomery, Alabama.

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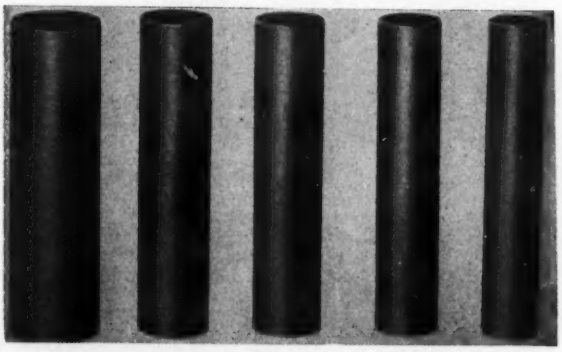

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FOAMGLAS PIPE-INSULATION

The first pipe insulation that can be used for both hot and cold lines, indoors and outdoors, is the new Foamglas insulation developed by the Pittsburgh Corning Corporation, according to a recent announcement.

The new insulation, of cellular glass construction, is the ideal pipe protector for processing industries where exact temperature control is required, wherever heat is to be retained or excluded, it was stated. Its cost, on an annual basis, is less than other insulations.

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PHILIPS APPOINTS NEW OFFICERS

P. van den Berg, who was formerly Vice President and General Manager, has been appointed President of the North American Philips Company, Inc., according to an announcement made by the Board of Directors.

Other officers of the corporation are L. J. Chatten, Vice President and General Commercial Manager; A. Worsnop, Treasurer; T. R. Naughton, Secretary, and L. J. A. van Lieshout, Assistant Vice President.

A. Vernes has been appointed President of Philips Export Corporation, succeeding Mr. van den Berg, who now becomes Chairman of the Board. H. G. Noordberg is newly appointed as a Vice President and F. T. Page as Treasurer. The other officers are M. M. N. J. Dorenbosch, Vice President, and T. R. Naughton, Secretary.

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RARE OPPORTUNITY: Glastechnische Tabellen by Eitel, Pirani and Scheel. Physikalische und Chemische Konstanten der Glaser. 714 pages, Berlin, 1932, $50.00. Mary S. Rosenberg, Publisher, Bookseller and Importer. 100 West 72nd Street, New York 23, N. Y.

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